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# SEA-COAST EROSION

. . AND . .

# REMEDIAL WORKS.

BY

R. G. ALLANSON-WINN, M.INST.C.E.I.

THE FASTNET ROCK

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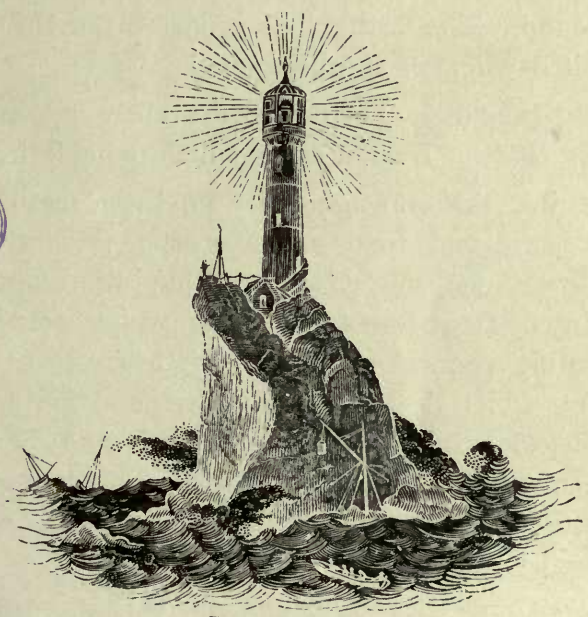

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# INTRODUCTION.

Since the interest surrounding all questions connected with alterations in the coast-line seems to be on the increase rather than on the wane, it has occurred to the author that the present time may be a suitable one for reproducing the articles on the subject which have recently appeared in four consecutive numbers of PUBLIC WORKS.

We know that the ravages of the sea annually cause heavy losses to individuals and corporations, and that rates go up with alarming rapidity and pertinacity in seaside towns where the sea's advance is steady; we also know, and this affects the country at large, that considerable sums of money have to be voted for the construction of harbours, which silt up and become practically useless in a few years, much of the money expended being thus wasted on injudiciously constructed works on ill-chosen sites. An excellent illustration is furnished by any wasting shore in the neighbourhood of which a silted-up harbour is to be found. The material is eroded from the place in which it is wanted and deposited where it is not wanted.

It is extremely difficult to keep harbours clear of sand, and nearly every harbour on the east coast of Ireland leaves much to be desired in this respect.

One would think that our ignorance on these matters should induce a healthy desire to learn, and that, as the matter is clearly one of national importance, the Government might well consider the question of establishing a properly appointed Department of State which could devote its whole attention to scientific enquiries and investigations. At present there are several Departments which deal with foreshores and harbours—amongst them the Board of Trade, Board of Agriculture, Woods and Forests, Treasury and Admiralty. It seems possible that there is work enough to give one Department plenty to do, and the establishment of such a Department is what I have strongly advocated for several years past.

R. G. A.-W.

# SEA COAST EROSION AND REMEDIAL WORKS

BY R. G. ALLANSON-WINN, B.A., M.INST.C.E.I.

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## Part I.—FIRST AND SECOND IMPRESSIONS.

IN regard to sea phenomena there are so many points at present imperfectly understood, and so many factors involved in the consideration of the causes of erosion and accretion, that one approaches the subject, if not with diffidence, at least with an open mind and a sincere desire to learn more and also, if possible, to throw some additional light on those portions which appear to be somewhat obscure and neglected.

In the present series of articles an attempt will be made to deal as far as possible with facts and to give the results of practical experience and observations.

It is proposed, therefore, first of all to enquire into some of the causes which bring about those troublesome alterations which primarily draw our attention to the coast line and then to pass on to the question of protective measures.

We have shifting winds, currents varying at different depths in direction and intensity, the daily change of tide, the never-ceasing alterations in submerged banks, causing the currents to impinge with ever varying effect upon the neighbouring shores and, possibly worst of all, we have the absolutely indeterminable concurrences of exceptionally high tides and storms.* Startling indeed are the results of these storms on occasions, and the task of collecting all the data really necessary before setting to work often seems well nigh hopeless. In no two places are the conditions precisely similar, and a very great deal of judgment is necessary to avoid a useless expenditure of money.

In a letter to the *Times*, dated Oct. 4th, 1899, the author called attention to the importance of scientifically watching the coast line all round these islands. The letter contained, amongst others, the following paragraphs:—

"At the present time there is absolutely no official and reliable record of the changes annually taking place round our coasts, and these changes are constantly affecting buildings and other works which have been carried out at a large outlay of public money.

"The Admiralty charts are excellent for deep-sea soundings and for the purpose of navigation, but they contain very little information on the question of currents affecting the coast line, and it would require the careful attention of a Department, or distinct branch of a Department, to keep a satisfactory record which could be relied upon when the time for action arrived.

* "Transactions of the Inst. Civil Engineers of Ireland," vol. xxviii., pp. 124 to 185.



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"Amongst the duties of the suggested Department the following may be enumerated:—(1) The systematic and repeated taking of sections (over the same lines) on all shores, as well as contours of high water, low water and mean sea level lines; this latter is very important, as much damage is done during storms taking place at half-tide. (2) The taking of soundings. (3) Calculations based on observations respecting the varying rates and directions of currents at high water, low water and mean sea level. (4) Observations as to the velocity and *vis viva* of waves. (5) Observations on the travel of beach, sand and other material, especially round headlands, piers, breakwaters, and across bays and the estuaries of rivers.

"The Ordnance Survey maps are, of course, admirable, but they only show the changes in high and low water marks at long intervals of time. What we require is a succession of observations by means of which any mischief may be readily detected and dealt with in its initial stage, on the 'stitch in time' principle."

In reply to communications on this subject the Board of Trade and the Board of Agriculture wrote letters to the author which, though not exactly encouraging, showed that the question was in their opinion one of public interest.

In 1899 the Council of the British Association appointed a committee to consider further the question of erosion of coasts round the British Isles already reported on to the Association by previous committees; and this committee has arranged, by the kind assistance of the Admiralty, to obtain returns of changes noted from time to time in the shores of the several coastguard districts along the coast, of any protective works which may be carried out, and of the effects produced by such works.

The last paragraph appears in a foot-note in the "Minutes of Proceedings of the Institution of Civil Engineers," vol. cxxxix., Session 1899-1900, Part I., and the author of this article mentioned in his paper, "The Constructive Power of the Sea" ("Transactions of the Institution of Civil Engineers of Ireland," vol. xxviii.), that the proposal does not go far enough, though doubtless a step in the right direction has been taken.

It is obvious that the coastguards are not in a position from their training and equipment to take the sections, make plans, and keep records in such a manner as would be serviceable to engineers when called upon to execute works. It would, for instance, be very difficult for a coastguard man, however intelligent, to give a satisfactory account of the "effects produced" by protective works unless he had taken sections, etc., when the works were started, and could compare them with later sections, etc.

The author is still of opinion that the State might take the matter up as such matters are taken up and looked after in Germany. He is informed, for example, that Professor Engles is in charge of a considerable experimental station called the "Flussbau Laboratorium," or river building laboratory, in Dresden, where experiments are being carried out directly under and with the support of the Government.

In this School of Instruction are to be seen models of the big rivers, and the Professor is enabled, by regulating the supply of water and by the introduction of various coloured sands, etc., to give a good idea of what happens in time of flood and in time of drought. Contours of the channel beds of many of the great German rivers have been laid down with great accuracy in the models, and, by the introduction of miniature breakwaters and other obstructions, or by the cutting of channels, the Professor can give good ideas of what would happen if the changes were made in reality. The alterations are, as it were, *tested*, and the engineers, being forewarned, are able to avoid falling into error and expending money uselessly.

The report of the committee, above alluded to, was presented at this year's meeting of the British Association, and contains much that cannot fail to interest the general reader, but the information is necessarily of a somewhat sketchy and superficial character.* It would appear that if the Government seriously took the matter up, and instituted scientific investigation—such as is now receiving support and encouragement in Germany—much good might result, and the movement would be attended by far less expense than the reckless expenditure of public money, as recently suggested, in costly and possibly ineffective protective measures undertaken with insufficient knowledge of conditions and circumstances.

From the preceding remarks it will be gathered that, in order to arrive at a proper appreciation of some of the difficulties which beset the

* *Vide* report on Cork and Kerry of the Committee (consisting of Sir Archibald Geikie, Capt. E. W. Creak, Prof. L. Vernon-Harcourt, Mr. A. T. Walmisley, Mr. W. Whitaker, and the general officers appointed by the Council) to the British Association.

foreshore engineer, one should at least have a rudimentary knowledge of the methods to be adopted in surmounting those difficulties, but, to judge from the guileless line of action often adopted by corporations and private individuals alike, one would almost think that the environment of a sandy shore, a boat, and a bathing machine were capable of supplying all the education necessary for the business.

Observation is essential, and much of this can be acquired by residents on the spot, but education is necessary to make it effective; in the same way mere experience, *i.e.*, observance of the succession of events, is inoperative without an intelligent understanding or interpretation of what has been observed.

The hydrographical surveys constantly being carried out by the Lords Commissioners of the Admiralty are of great value for the detection of banks in process of formation and the other changes which are taking place on the sea bottom. There are, however, only ten vessels employed for this gigantic task both in home and foreign waters, and it can be readily understood how slow must be the process.

Quite recently a very careful inspection was instituted upon the east coast near Ramsgate with regard to the appearance of some shoal ground which was reported to be present in the vicinity of the Elbow buoy off the North Foreland. It was the more necessary to examine this locality, as the shoal lay right in the course of large steamers and vessels bound for the Thames. The search occupied a full month, as the sounding operations were greatly impeded by the persistent and strong north-easterly winds experienced. It was found that the ground, though apparently of hard material, has very much changed since the last survey, made only five years ago. The result is that in consequence a much wider berth must be given by passing craft to the Foreland. The survey of the Bristol Channel proved that considerable changes had taken place in the Welsh grounds. The portion of the middle ground, which dries at low water, has extended a good deal to the eastward and grown eleven feet in height since the year 1893, while the channels and sands north of it have moved considerably northward.*

It would seem that an extension of these hydrographical surveys, embracing also the question of actual foreshore alterations and the taking of observations and keeping of records, as above suggested by the author, would throw a great deal of light on the whole subject of foreshore protection, but the number of surveyors would have to be greatly increased, and the expense would be considerable.

On being requested to report on any foreshore the engineer should direct his attention to the following points, upon which he should collect as much information as possible:—

1. Range of tide.
2. Direction and intensity of prevalent winds.
3. Direction and intensity of most destructive winds.
4. Direction and force of 'long-shore currents, surface and bottom velocities being taken at high water, mean tide and low water.
5. Percentage of material, per cubic foot or yard of water, carried in suspension. Samples to be taken from surface and close to the bottom.
6. Quantity of shingle or other detritus, and extent to which it is moved during different conditions of wind, waves, tide, etc.
7. Nature and depth of the marl, sandstone or other material undergoing erosion.
8. Extent to which the sea bottom is undergoing change, especially in the matter of the formation or alteration of submerged banks causing alterations in the directions of currents.
9. Nature of material thrown on shore during on-shore gales, and the depth of water from which the material is torn.

The author has repeatedly noticed that when any important works are about to be started, the greatest attention is bestowed upon the surface currents and experiments are conducted with floats, etc., whilst the material-bearing and material-shifting currents near the bottom are, by comparison, neglected.

It is known that currents are frequently found in deep water—especially off estuaries, etc.—running in directions diametrically opposite to the surface currents, so that, if we are to know something about the action of such currents, we must study them in conjunction with the wave and storm factors—not alone by corks and floats on the surface, but also by recording instruments near the bottom.

At Youghal, Co. Cork; Bray, Co. Dublin; and Glenbeigh, Co. Kerry, as well as at many other seaside places in England, Scotland and

* *The Engineer*, August 8th, 1902.

Ireland, considerable quantities of material are torn from the sea bottom, in depths far below low water level, and cast up on the shores. For example, at Youghal, after the severe on-shore gales of January, 1903, the shore was literally strewn with stones of various sizes. Some bore evidence of considerable attrition whilst others, with sharp edges, had clearly been freshly torn from their positions by the agency of the storm

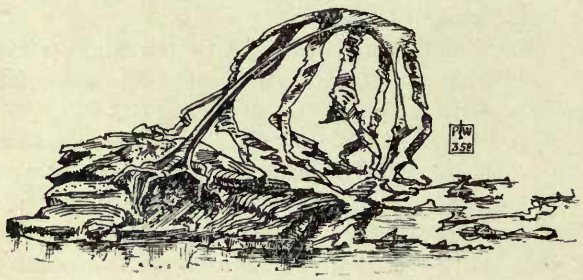


**Fig. 1.**
LARGE FRAGMENT OF SANDSTONE; WEIGHT 50 LBS.

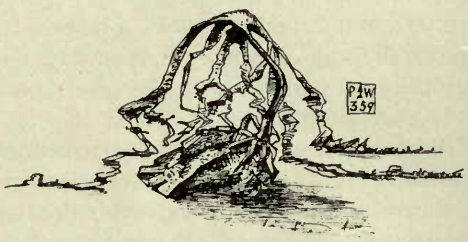


**Fig. 2.**
FRAGMENT OF LIMESTONE; WEIGHT 3 LBS.

The sharp edges shown on both these stones show they have only just been torn from their beds in the strata to which they belonged.

acting on the long deep-sea weed attachments *(Laminaria Digitata)*, which had caused them to be thrown on shore. Some of these stones weighed 40 to 50 pounds and the seaweed attachments were often over 6 ft. in length. Now, as these weeds are only found in deep water, *i.e.*, depths below low water level, and the stones, sand, shells, etc., are firmly attached, there can be no doubt that erosion is going on in the offing and in situations inaccessible to ordinary walls and groynes. That heavy material is often moved in from depths of 10 fathoms is now no longer a matter of doubt—it is a proved fact.

We will now suppose, for the sake of argument, that 100 cubic yards of material has been thus cast up on a particular shore, and that it is conclusively proved that it came from the deep water off shore. It will be readily admitted by most people that on the removal of this mass of material there is deeper water above the situations from which it was moved than there was before, and this, on a sea bed sloping upwards towards the shore, must indicate the nearer approach of deep water. No other interpretation seems possible, and this advance, taking place miles out at sea and in several fathoms of water, cannot well be connected with the surf or breaking-wave action between high and low water marks on the visible shore.

A comparison of the conditions obtaining at Glenbeigh and other places, as well as on the east coast of England, led the author to search for some explanation of the phenomena.

Two circumstances were apparent at these places. The sea was encroaching rapidly, and the substratum was soft in each case, and, unless some connection could be established between the erosion caused by surf or wave action and that which is clearly caused by the movement of material composing, or lying on, the sea bottom below low water level, it would seem impossible to remedy both evils by dealing with one alone.

The author found that material lying immediately beneath the mountain waste at Glenbeigh was soft yellow sand, and that soft material extended for some depth below low water level. He also found that the glacial drift, sand, laminated clay and other soft material composing the Holderness coast of Yorkshire extends to a depth of 100 to 200 ft. before the hard chalk is reached. These circumstances led him to consider that possibly the two erosions, though going on simultaneously at both these places, may be so far independent of one another that the checking of the one would by no means necessarily stop the other.

After long continued observations and careful consideration the author is inclined to believe that, in all situations where the encroachment of the sea is steady and continuous, *and the material is of a soft and easily eroded nature for a considerable depth below low water level*, protective works erected on the visible shore cannot be expected to afford more than temporary relief. In such cases we are fighting an inaccessible foe, as it is hardly to be supposed that devices on the small stretch of beach or sand between high and low water marks can materially affect the action of currents and wind waves operating, say, down

to the 5-fathom or 10-fathom line. Further evidence in support of this theory will be furnished in forthcoming articles.

Here, parenthetically, the author may be permitted to explain the difference between the "deep sea" of the foreshore engineer and the "deep sea" of the hydrographer. The former looks upon anything below low water level as "deep" because of the increased difficulty which is occasioned by having to work *in* the water all the time; the hydrographer, chiefly concerned with soundings and specimens brought to the surface by the tube, probably considers 20 fathoms almost shallow water.

calculations respecting the hardness of the material attacked. The travel of flint shingle is responsible for much erosion where rocky shores are concerned, though possibly in such places the alterations—could observations be made to fix the extent—might only amount to a few inches in 100 years. There are also places, *e.g.*, Bray and Hastings, where the travel of shingle greatly accelerates the erosion of softer material, such as marl and sandstone.

It has been estimated that some 3,000,000 tons of detritus—mud, sand and shingle—are eroded each year from the Holderness coast between Bridlington and Spurn Point, and the

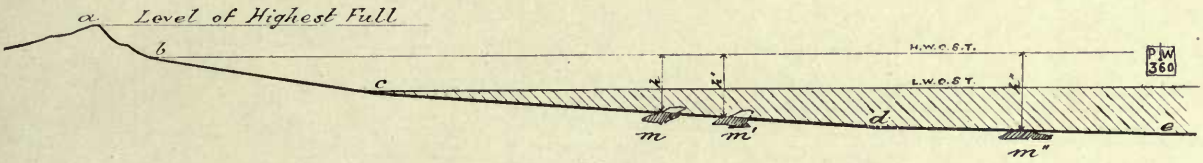



**Fig. 3.**

In this figure, *a*, *b*, *c*, *d*, *e*, is a section which shows the visible shore, *a*, *b*, *c*, and the sea bottom, *c*, *d*, *e*, below low water level. In the latter portion are shown masses, *m*, *m'* and *m"*, which are moved in shore by the action of storms, and often thrown by the waves as high as the highest full of beach. It will be seen that the removal of these masses cannot but increase *h*, *h'* and *h"*, the depths of water, and that deep water therefore *advances on the land.*

The consideration of protective works being reserved for a later article, it may be advisable to now refer to the march of the sea as it is occasionally recorded by history or tradition. An examination of the records of several places on the east coast of England tends to prove that in the olden days towns and villages stood directly over the site of the present 5-fathom line—*i.e.*, there is now a depth of 30 ft. of sea water where formerly dry land alone was to be found. Here again we observe the advance of deep water; and since it is improbable that the general inclinations of the shore and sea bottom have very materially altered since the old days, we may fairly suppose that when those ancient towns existed the then 5-fathom line was a mile or so out to sea—*i.e.*, two miles from the present coast line.*

Again referring to Glenbeigh, observations since 1842 reveal the fact that the encroachment of the sea at one portion of the foreshore has been 1050 ft. in sixty years, or an average of over 17 ft. per annum. On the Holderness coast of Yorkshire the annual erosion may perhaps be from 5 to 20 ft. according to the locality between Bridlington and Spurn Point. The rapidity with which the changes are effected depends so much upon the situation that it would be useless to attempt to lay down any rule based on

consideration of the ultimate destination of this vast annual loss and gain is reserved for a future article.

As regards the magnitude of time involved in many of these changes, we are reminded that the human epoch is to the geological epoch as the microbe is to the megatherium, and that, therefore, when we are able to note any very considerable geological changes taking place well within the limits of an ordinary lifetime, we should seize with avidity the opportunity afforded for investigation.*

It may be mathematically proved that no particle of material can be eroded from a sloping sea bottom—*i.e.*, where the slope is the continuance downward of a shelving shore—without a corresponding deepening of the sea at that point and an advance of deep water on the land.

It is also known that countless agencies, such as marine borers, shell fish, etc., are constantly at work disturbing material which is then more readily moved by storms and currents.

Another very fruitful source of deep-sea erosion, which has received very little attention, is that which has only recently been discussed in connection with foreshore changes, viz., the movement of material by submarine fresh water springs,

* *Engineering*, July 24th, 1903.

* "Foreshore Protection." Transactions of Society of Engineers, 1899, pp. 133-160.

such as the Hessle Whelps or Bridlington intermittent springs.

The author's attention was first called to this on reading various papers connected with submarine cables, the fractures in which it is thought may often be caused in very deep water—many hundreds of fathoms—by the action taking place at the exits of submarine rivers and springs.

In reading through the papers* and letters on this subject it is impossible not to be impressed by the weight of evidence in favour of the shifting of material lying at the bottom of the ocean in very deep water, and adopting an *a fortiori* line of argument, one would suppose that if such

That the two chief causes are not necessarily connected seems to be sufficiently apparent by the distances both horizontal and vertical, the one being confined to the short extent of the visible shore and the range of tide, whilst the other is operating at a distance of many miles in the offing, and in 30 to 60 ft. of water. If, therefore, this erosion below low water level continues to aid the advance of deep water landwards, we find ourselves confronted by an inaccessible foe. It is impossible to controvert the fact that deep water now exists in many places immediately below the former sites of towns and villages, nor can it be denied that this

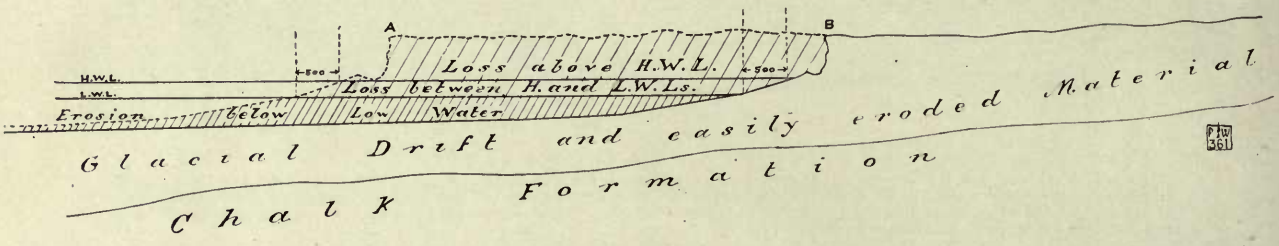



**Fig. 4.**

The section from which this is reduced was drawn to a longitudinal scale of 1000 feet to an inch as compared with 100 feet to an inch vertical, and shows the former and present position of cliffs. The horizontal extent of the shore is taken at 500 feet (as shown); this distance has remained practically constant during the whole period of erosion. The general curve of the coast line has remained much the same during this period.

movement of material can be brought about by these agencies in great depths where the pressure of the sea water must be enormous, movement will also be possible in the shallow water of the North Sea where the pressure is not nearly so great.

We have then in all cases, where the coast material is of a soft and easily eroded nature for any considerable depth below low water level, to take the following into consideration:—

| | |
|---|---|
| Chief Causes. | 1. The surf and wave action, aided by currents, on the visible shore between high and low water marks. |
| | 2. The erosion going on below low water level, perhaps many miles distant, and in 5 to 10 fathoms. |
| Contributory Causes. | 3. The action of countless borers, shell fish, worms, eels, etc. |
| | 4. The action of submarine springs. |

* "Submarine Gullies, River Outlets, and Fresh Water Escapes beneath the Sea Level," by Henry Benest, *Geographical Journal*, October, 1899, vol. xiv., No. 4.
"Oceanography," by Sir John Murray, *ibid.*
"Sub-oceanic Changes," by John Milne, *Geographical Journal* for August and September, 1897.
"Repairs to the South American Company's Cable off Cape Verde in 1893 and 1895," by Henry Benest. *Electrical Engineers' Journal*, May, 1897, vol. xxvi.

is deep sea erosion, and that it is now going on.

The sea is ever at work pulling down and building up, washing away and depositing, and the two processes are exactly equal as regards the particles moved, and merely represent a change of position of certain masses of material—what is taken away must be deposited somewhere. The softer the material the sooner it is eroded and carried elsewhere, but wherever the sea makes a dead set on the coast line, and continues long enough in the effort, the erosion goes on—rapidly with the sand dune, mud bank, soft marl, etc., etc.; slower with the chalk, and yet slower still with the rocks, be they sandstone, slate, granite or basalt. The geologist and foreshore engineer should always go hand in hand.

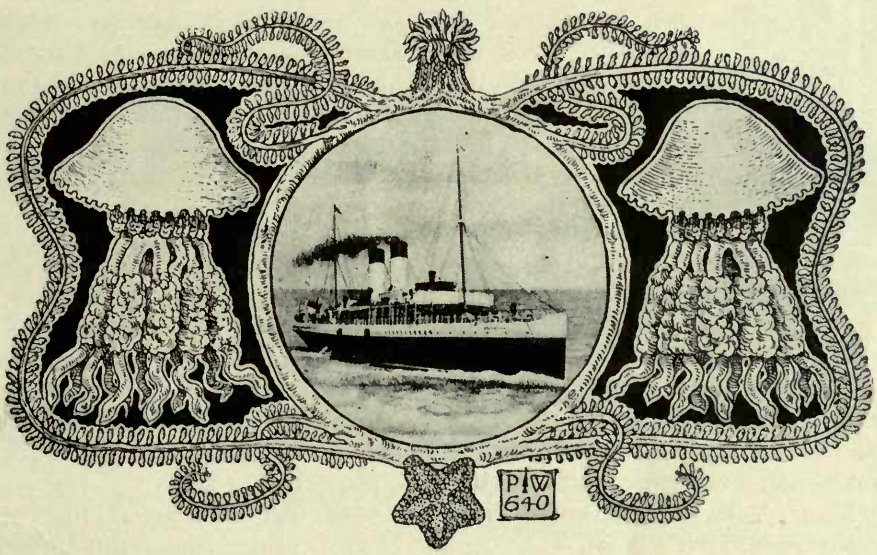
As regards the contributory causes above tabulated, it is possible to collect information as to the extent to which marine worms, etc., eat into both rocks and marls, and, if an estimate were made of the amount of material disturbed by such agencies over, say, one square mile of sea bottom, it would be found that a very considerable mass was eaten out of the sea bed, and rendered highly sensitive to the action of currents.

A perusal of Professor Boyd Dawkins' most interesting paper, "On the Relation of Geology to Engineering,"* gives a better insight into the action of submarine springs in situations where glacial drift lies above the chalk, as it does in Yorkshire. The paper should be studied in conjunction with the opinions of Professor John Milne, Admiral Sir W. Wharton, Mr. H. Benest, Sir John Murray, and Messrs. Matthew H. and Kaye Gray.

In concluding this article the author would draw attention to the danger of being led away by first impressions. It is to be regretted that so many of those interested in coast protection pay attention only to what they can see. The pounding action of the breakers, the tumbling cliffs and denuded beach all appeal to the senses and alone receive serious attention, the far more extensive areas of erosion below low water mark being practically neglected.

In most cases a little further study and research will reveal the existence of some hitherto unsuspected peculiarity—a newly formed submerged sandbank or an unknown deep current—which may entirely alter or modify one's ideas as to the best course to pursue.

* The "James Forrest" Lecture, March 17th, 1898. Proceedings of Inst. C.E., vol. cxxxiv.



# Part II.

## EROSION, TRANSPORTATION, AND DEPOSITION OF MATERIAL.

IN most shores undergoing steady erosion it is observed that, when no obstacle is erected to check the progress of the sea, the horizontal distance between high and low water marks remains practically the same from year to year; in other words the general slope of the shore continues unchanged whilst the sea advances.

An example of this is found at Glenbeigh, Co. Kerry, where we have approximately the same expanse of sand as we had in the year 1842—high water mark and low water mark having each advanced, in places, a distance of over 1050 ft. since that date (*vide* Fig. 9).

If low water mark had not advanced we should now have 1050 ft. more of visible shore than we actually have at present, and the gradient would of course be much flatter. As a matter of fact we have, in places, a shorter and therefore steeper shore than we had in the old days, which affords additional proof of an increase of erosion below low water level, but this is chiefly observed where the sea has been checked by the cliff and the protection works of late years.

Where, however, an obstacle is placed near high water mark and the sea's inland incursion is artificially checked by walls, etc., we observe, in situations such as we are considering, that low water mark continues its advance, thereby shortening the horizontal distance between high and low water marks, diminishing the area of the visible strand, and increasing the steepness of the shore.

In the first of the accompanying typical sections an attempt is made to illustrate what happens when the sea is steadily advancing, as at Glenbeigh, or on the east coast of England, and no wall is built to obstruct it, and in the second a wall is shown erected near high water mark on an adjacent portion of the same shore. It will be observed that so far from stopping the advance of low water mark the wall "protection" may greatly accentuate the mischief by causing a heavy back-wash.

The range of tide remaining constant, we now have a visible shore diminished in area and increased in steepness, and therefore an increased depth of water further inland. This is actually shown by the contour and sections of the Bray shore, where the practical results appear to completely support and bear out the author's theory, and we are forced to the conclusion that erosion below low water level is not only not stopped, but is even increased by the checking of the sea's advance at high water mark.

At Bray the erection of a high sea embankment—for the protection of the cliff on the edge

of which the railway line runs—has stopped the advance of high water, but has not stopped the advance of low water mark, which is now over 100 ft. closer to the wall than it was three or four years ago. All along this shore, especially during the periods of complete sand denudation, the erosion of soft material may be observed

1. Heavy back-wash scour from the wall.
2. Travelling shingle acting on soft material.
3. Casting up of material with deep sea weed attachments (a class of erosion previously alluded to).
4. Wholesale abstraction of shore material for sale by a neighbouring owner.

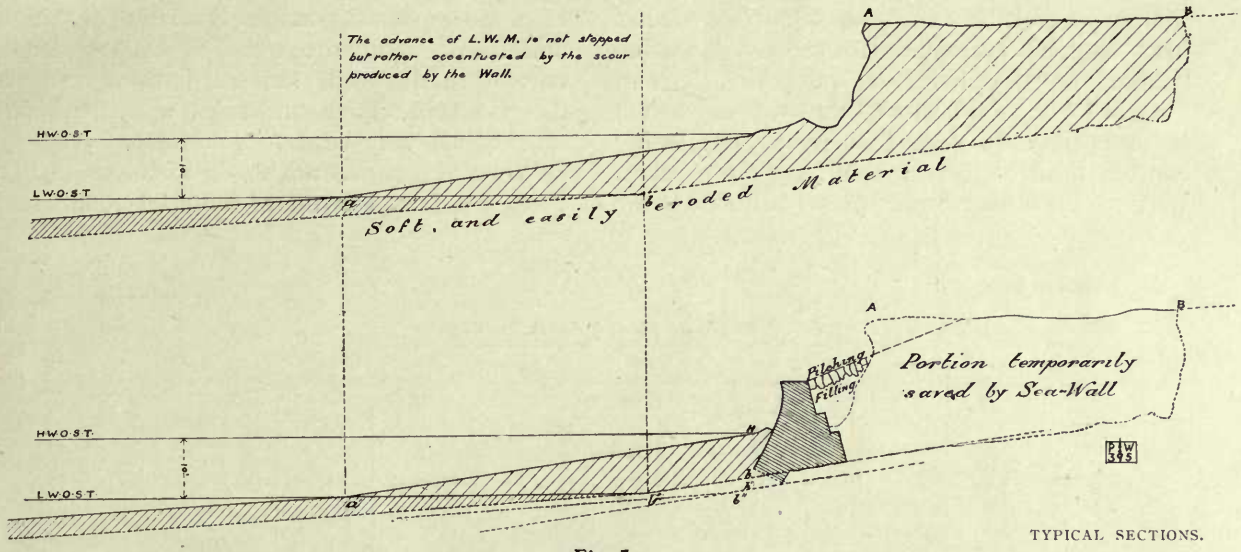



**Fig. 5.**

The upper section shows erosion on a certain coast in a certain number of years. The L.W.M. has encroached from A to B, the cliff in the same period having disappeared between A and B. In the lower section is a portion of the same coast treated with a sea wall, the foundations of which have been taken down 7 or 8 ft. into the marl. In the same number of years as in the former case the high water will have been checked by the wall, whilst low water will have advanced from a′ to b′—possibly to b″—on account of the scour from the wall. The cliff has been saved *pro tem.*, but there is a depth of 7 to 9 ft. in front of the wall, the foundations of which are undermined.

taking place well below low water level, and for a considerable distance out at sea. Much of this erosion is caused by the lateral movement of shingle rubbing away the soft marl which

The actual measurements and sections afford sufficient proofs that erosion below low water level is going on, and that deep water is advancing. *Vide* section and plan.

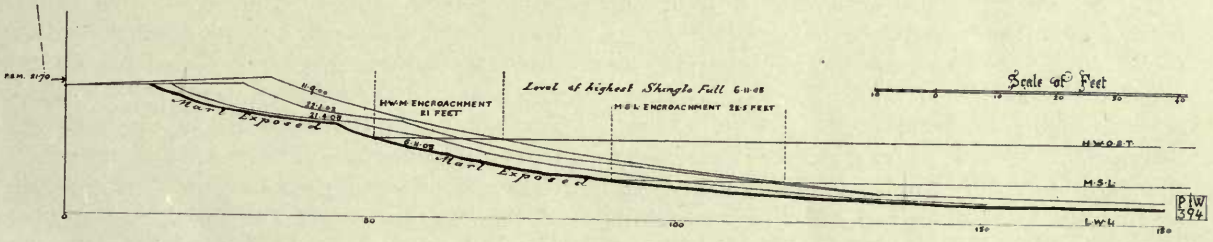



**Fig. 6.**

Since September, 1900, L.W.M. has encroached about 120 ft., whilst, as will be seen from the above section, M.S.L.M. and H.W.M. have advanced 28 ft. and 21 ft. respectively, in the same period. This heavy loss of shore material is to a great extent accounted for by the abstraction every year of many thousands of tons of shingle and gravel from the immediate neighbourhood.

extends to deep water, as well as by its movement up and down the beach, which in places is cut in deep furrows at right angles to the coast line.

On this shore there is no doubt at all about the deepening of the water below low water level, and the mischief is brought about by the following causes:—

Since the erection of nine Case groynes (as shown on the plan) some three years ago, sand has accumulated in quantities previously unknown, and this covering to the marl, remaining as it does for several months in the year, retards the process of erosion. These same groynes have also been instrumental in such a

marked improvement in the shingle bank that no fresh toe-walls have been required, and the foundations of the wall have been well covered by beach for the entire distance protected. But the groynes—useful though they have been—will not work miracles; they will not affect the alterations in the sea bottom beyond their reach and "out of their range," so to speak.

Here we feel the want of a definition. It has been so long customary to talk of "beach," "shore" or "foreshore" as quite distinct from "sea bed" or "sea bottom," that we may be led imperceptibly to regard them as not being continuations of the same surface. In previous writings the author has frequently alluded to the

Our knowledge as to the direction and intensity of those deep sea currents, which cause alterations in the coast line, and are instrumental in conveying enormous masses of shingle and sand from one locality to another, is at present far from complete. The finer particles of the eroded material are carried long distances in stormy weather by wind waves and surface currents, but the more important portions, consisting of shingle and coarse sand, are removed by the deeper currents acting near the sea bottom, and the directions in which these latter currents are moving are very hard to determine.

When statements are made to the effect that there can be no travel of material round such

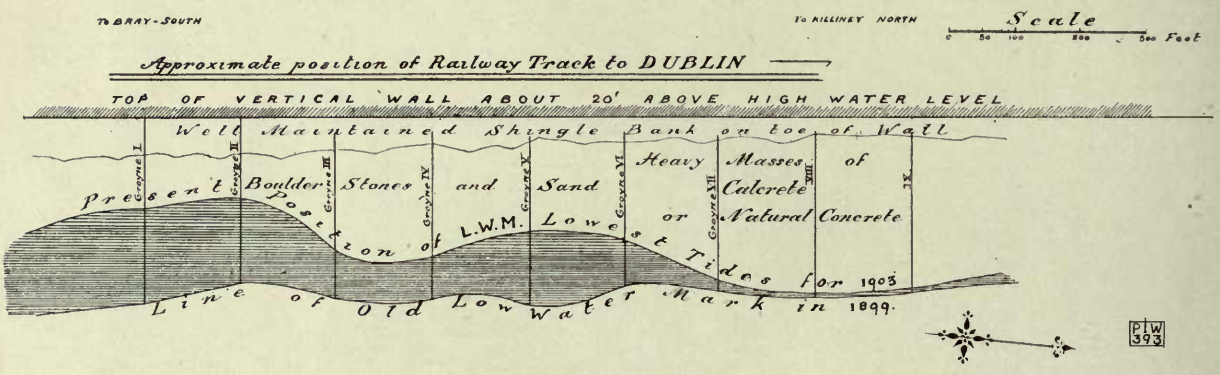



**Fig. 7.**

Since the erection of the groynes sand has periodically appeared in considerable quantities all along this portion of the shore, especially during the summer months. The shingle bank also lies more evenly along the toe of the wall than it ever did previously to 1899. The maximum encroachment of 150 ft. is shown in the neighbourhood of Groyne I., and the average, over a frontage of about 1500 ft., is about 70 ft.

shore as a bank with very flat gradient *the toe of which extends to low-water mark.* A far more correct definition would be a bank *the toe of which often extends to deep water, and is to be found at the junction of the marl, glacial drift, or other soft material with the rock, chalk, or hard material.* This will appear clearer if we regard the sea as a great basin which, through the tides, seems to us to be more full of water at certain times than it is at others. The visible shore—*i.e.*, the portion exposed between tides—is the rim of the basin, but is none the less part of the same vessel. So that it would seem correct to regard as the sea bed all surfaces actually beneath the sea at highest spring tides.

In this way we shall more readily eliminate from our minds the popular fallacy that all our troubles begin and end in the changes we observe on the little strip of visible shore between high and low water marks.

and such headland or across such and such estuary they should be received with caution. In very rough weather the sea is almost always discoloured for a greater or less distance from the shore, the discolouration indicating the presence of matter held in suspension, which matter is of the colour of the neighbouring cliffs or sands. Thus we observe, in stormy weather off the Yorkshire coast, the discolouration is of a chocolate hue—the eroded cliffs being of a dark reddish brown. As we proceed further south towards Gibraltar Point this colour changes to a more sandy tint, and this change is still further accentuated as we reach Yarmouth and Lowestoft. Off Dover we perceive the milky colour of the sea, and at once put it down to the erosion of the chalk cliffs. In all such cases material is travelling, and it is equally certain that it will be sooner or later deposited *somewhere; where* we do not always know, because the deeper currents have

to be traversed by every particle before such particle can reach the bottom.

What we *see* is the surface of the water in a state of agitation and, from its colour, we know that it holds solid material about to be deposited when the rough weather ceases. Ocular evidence also tells us the direction of the wind waves, and float experiments will give us the surface currents. During the violent churning action which goes on in severe storms it seems probable that the proportion of sediment or suspended matter is heaviest near the bottom and lightest at the surface of the sea. The shingle and coarser particles of sand are always lying on the bottom, except when temporarily moved by waves or currents, and from these directly up to the surface the proportion of solid material would be constantly diminishing. It is somewhat analogous to stirring up a cup of thick coffee; first of all the "grounds" settle and then, far more gradually, the surface clears—the finer particles descending and being visible in the lower part of the cup long before the whole cup can be called quite clear.

From the above mentioned considerations it appears to the author that estimates as to the travel of material based upon observations with floats, bottles, etc.. on the surface alone cannot but be misleading and valueless.

We really require more knowledge about those currents which are directly affecting the heavier particles lying on the bottom and which must also therefore affect every single particle moved by the water *whether held in suspension or moved along the bottom*, for, as indicated above, no particle can be deposited on the bottom without being acted upon by bottom currents in all places where such currents exist. The author has observed, in clear rivers and in the neighbourhood of sills, banks, etc., leaves, pieces of paper, etc., evidently of about the same specific gravity as the water, carried along near the bottom in a direction diametrically opposite to that in which the surface current was flowing. In these cases the presence of certain obstructions accounted for the phenomenon and caused the eddy or undercurrent of water circling back in the direction opposite to that of the surface stream.

This simple instance in the case of a river's flow may serve as an illustration in miniature of what is constantly going on in the neighbourhood of those vast ridges, ledges, banks, and gulches which are known to abound on the ocean bottom, and it is not difficult to conceive that, wherever the tide runs strong, powerful under currents may be set up capable of carrying general detritus great distances in directions quite undeterminable by surface current observations.* In order to remove some of the uncertainty which at present prevails it would probably be desirable to take many observations at places where the erosion of the coast line and travel of material cannot be accounted for or is little understood. Such observations would include:—

1. Surface directions and velocities.
2. Soundings and bottom directions and velocities.
3. Examination of all material whether in suspension or lying on the bottom.

The surface observations may be made with corks or the surface float designed by Captain Cunningham or the twin floats with one on the surface and the other, of greater s.g. than the water, attached to it and hanging below it.

For the deep sea currents the author has designed an instrument consisting of a heavily-weighted hollow rod, the weight at the lower end of which must be sufficient to insure considerable tension and hence the vertical position of the rod. A vane is attached to the rod which can be clamped in any direction it may take up through the action of the currents. Attached to the vane is any current meter of approved pattern, and on the higher portion of the rod is fixed a compass also capable of being clamped simultaneously with the vane and meter. By the use of this apparatus, which was fully described by the author in his paper read to the British Association in Belfast in September, 1902,† it is possible to make four observations at each lowering to the bottom of the sea:—1. Direction of the current at bottom. 2. Its velocity. 3. Depth of the water. 4. The nature of sand, etc., lying on the bottom—this latter being accomplished in the old way, so well known to sailors and fishermen, of putting tallow or lard on the lower side of the sinker, and so catching any small particles. The apparatus is simple and strong, and there are no springs or delicate mechanism—with the exception of the compass—to get out of order.

*"Repairs to South American Company's Cable." Journal Inst. Electrical Engineers, Vol. xxvi. Discussion on Paper by H. Benest, p. 254.

†"The Direction and Velocity of Material-bearing Currents with Description of Current Indicator," British Association, Belfast, 1902.

The irregularities of the sea-bottom, pieces of sea-weed, etc., are apt to interfere with the free action of instruments of this class, so that *no single observation at any one place should be relied upon*. Several should be taken, and a mean then struck which could be relied upon as sufficiently accurate for the purpose.

The author believes that, with the aid of this and a few other appliances, highly important discoveries might be made over certain lines. Sections could then be plotted and information afforded respecting the conditions prevailing at various times of tide both on the surface and near the bottom.

One serious drawback—possibly the most serious—appears to be that we are precluded from conducting any observations from a boat *in very rough weather*, and it is during the worst storms that such experiments and observations would lead to the most valuable results. In order to observe and take records of what is going on off-shore during the continuance of heavy gales some fixed contrivances would seem necessary, and they might be connected, by means of electricity, with the shore. The objection to these, however, is that they might be either torn away or else buried beneath hundreds of tons of shingle or sand, which a single storm will often accumulate to the depth of several feet.

Although observations from a boat can only be made in what may be called fine weather, a great deal respecting the tidal flows and the relative effects produced by upper and lower currents might be ascertained by careful experiments.

But the results of such observations do not place us in a much better position as regards knowledge of storm effects. We may read that: "Observations off such and such a coast show nothing but clear water, clean sand and fine shingle"—quite so, at that particular time, but had it been possible to observe during very rough weather the water would have been turbid and the material at the bottom in a state of agitation or movement. On the authority of Sir G. G. Stokes and Lord Rayleigh, we are assured that waves produce an effect at considerable depths. The former says in his correspondence with Mr. A. R. Hunt: "I think that even with a depth as great as forty fathoms the effect of the waves is not to be disregarded, at least in the case of a locality subject to oceanic swells, and where there is a sensible tidal current as well."* Now forty fathoms is very deep water for the North Sea; indeed there is seldom over thirty fathoms between the Yorkshire coast and the Dogger Bank, so that we may not be far wrong in imagining that the whole of this sea bottom may be undergoing change through the action of waves and currents.

The author doubts whether any scientific investigation of natural phenomena has ever given rise to so many conflicting opinions as that involving the collection of evidence and data connected with the travel of material round the coast. If space admitted, he could give numerous instances in which experts of the highest standing have given opposite opinions on matters which should not be matters of opinion at all, but matters of fact.

Probably the most remarkable evidence respecting this hitherto vexed question is brought forward by Mr. Kinahan in his description of "Beaufort's Dyke"—the extensive submarine gulch in the North Channel between Scotland and Ireland.†

The question was raised by the proposed construction of a submarine tunnel between Donaghadee in County Down, and Port Patrick in Wigtownshire. "In the sea between Ireland and Great Britain there are various perplexing and unexplained deep-sea currents that go under various names according to the localities, such as races, dykes, ditches and undersucks, etc. These are conspicuous in connection with the sand-banks off the Leinster coast. The 'races' are not the ordinary 'tidal race' in a narrow channel, but a current that starts off nearly perpendicularly to the coast line, towards the 'tail' of one of the banks. All these different currents vary in accordance with the state of the tide, being generally more conspicuous during the Spring tides than the Neaps. These variations, especially of the undersucks and ditches, are so vagrant that, as a general rule, the fishermen are afraid to shoot their nets inside the banks off the south-east coast. On this account it was proposed, some fifteen years ago, that the Royal Society should apportion a part of their

* "The Skerries Shoal." Trans. Devonshire Association, 1887, xix., pp. 498 to 515. "Start Point to Petitor." *Ibid.*, by Arthur Roope Hunt, 1902, xxxiv., pp. 482-495.

† "The Beaufort's Dyke, off the coast of the Mull of Galloway," by G. H. Kinahan, Dist. Surveyor (Retired) H.M. Geol. Survey. Proceedings of Royal Irish Academy, 3rd Series, Vol. vi., No. 1.

Scientific Grant to investigate these obscure currents. As, however, at that time there was no competent person disengaged who would undertake the investigations, the proposal fell to the ground."

Haughton's investigations of tide phenomena between Great Britain and Ireland prove that the "head of the tide surface" in the Channel is in the neighbourhood of the Isle of Man. He defines the head of a tide as a place where the waters are "dumped up"—rising to the greatest height, but having no currents. To the southwards and northward of the "head of the tide" in the Irish Sea, there are the "hinge lines," or places where there is the least rise of tide and the greatest currents. Respecting this, Mr. Kinahan remarks:—"Haughton's definition of the 'head of the tide' is not quite correct. It ought to be no *surface* current. It is evident, as the water comes in and subsequently goes out below, there must be considerable deep-seated currents, as, indeed, is evidently proved in the estuary of the Mersey, the currents there being adjuncts of the great 'head of the tide' in the neighbourhood of the Isle of Man."

This dumping up of the waters takes place within forty miles of the southern extremity of Beaufort's Dyke, and, since the channel in which the Dyke lies is in places less than twenty-two

Fig. 8.

miles wide, we are not surprised to hear of powerful under-currents, though the author must confess that the statements respecting the shifting of enormous masses of shingle, etc., at the bottom of the gulch, at depths of from 100 to 144 fathoms (600 to 864 ft.), caused him considerable astonishment.

It has been contended that since the hydrographic surveys of Beaufort's Dyke reveal the existence of ooze, sand, mud and shells at the bottom of the gulch, there cannot possibly be

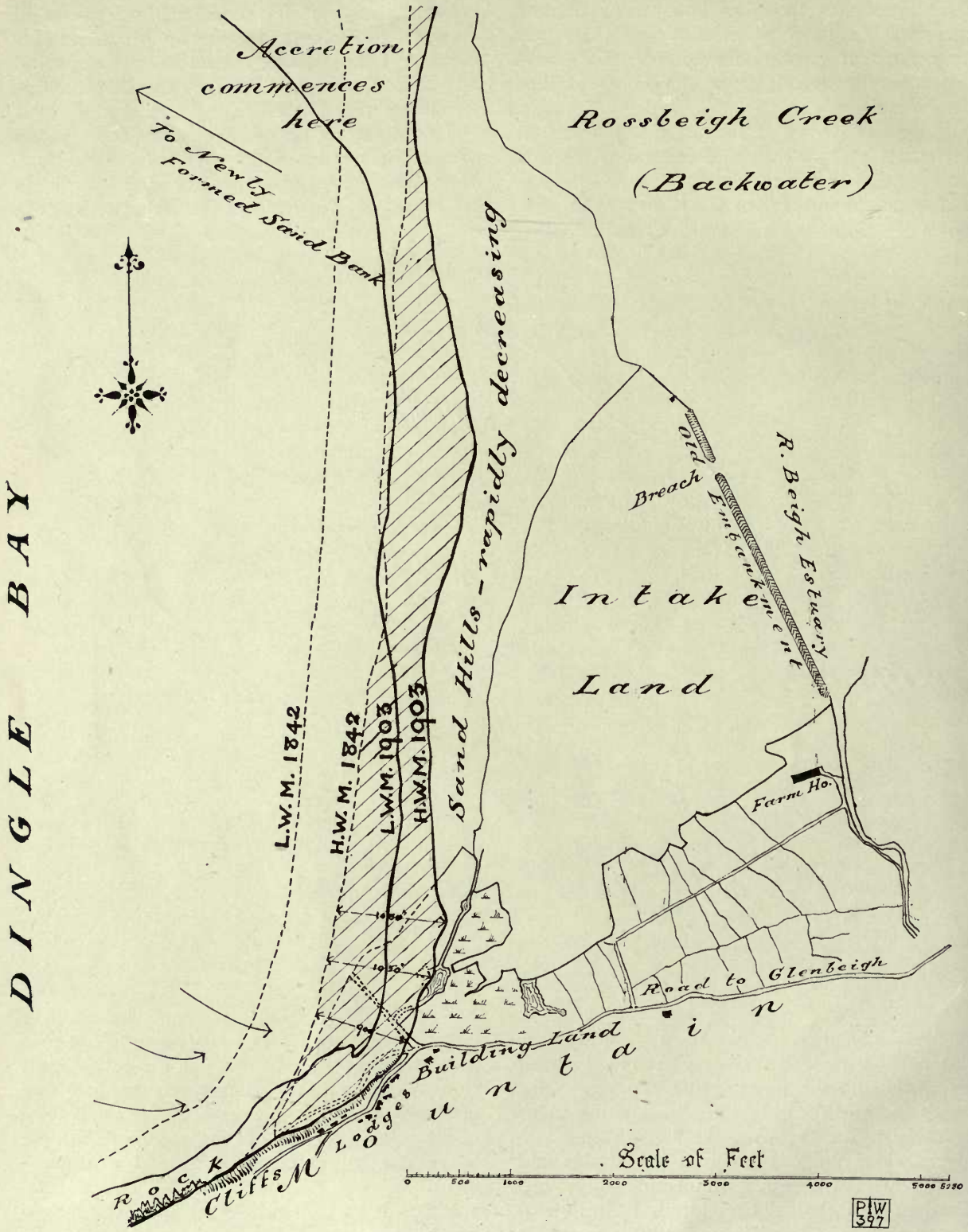



**Fig. 9.**

Heavy black lines show high and low water marks at present time. The dotted lines show the contours in 1842. Light shading shows extent of erosion since 1842. Curved arrows indicate the direction of eroding currents.

any current at that depth. As unanimity of opinion is in this instance conspicuous by its absence, some further investigation seems desirable. The soundings which appear on charts dated 1867, 1879, 1885, 1890, 1894, 1897 and 1898 may not have been taken *exactly* over the same spot on every occasion, and if they were not so taken the sections would be of little value.

It would seem that if we admit the deep current, we may also easily admit the shifting of sand, gravel, etc., to almost any extent. If, on the other hand, we admit the change in the configuration of the bottom of the gulch we are almost bound to admit the existence of the current, for by what other agency could the change be brought about? *

To return to more shallow water, we find that the changes in the sandbanks and bars in Dingle Bay, in the neighbourhood of the sandy promontories of Ross and Inch, have of late years been very remarkable, and it is noteworthy that the erosion of the most important portion of the foreshore has kept pace with these marked changes on the sea bottom. A newly formed bank, just submerged in high spring tides, now stretches westward for over two miles where formerly only deep water was to be found; and the author, whose experience of this coast extends over thirty years, is of opinion that the newly formed bank has caused the currents to strike with greater force upon this one particular portion of the coast. It is at least possible, or even probable, that there is some connection between the extensive erosion and accretion of banks and shores within three miles of one another—especially when the actions and results take place simultaneously. We may perhaps be allowed to call it strong presumptive evidence of a connection between the phenomena.

The changes in the neighbourhood of the Bar—*vide* small scale plan, Fig. 8—have recently been so rapid and so marked that the Admiralty only a few years ago issued an order forbidding the captains of gunboats to attempt the dangerous passage between Dingle Bay and Castlemaine Harbour.

To return to the Yorkshire coast. There appears to be abundant evidence that material, both shingle and sand, is carred down from the eroded cliffs of the Holderness coast in a southerly direction. Otherwise it is not easy to account for the heavy banks at and in the neighbourhood of Spurn Head. The trend is from north to south, and the author has always held the extensive accretions at the Humber estuary, at Skegness, Gibraltar Point, and the Wash, are due to the travel of material from the north either held in suspension and carried along by surface currents and wind waves or by deeper currents, and he thinks that in this case also the building up of large areas in the neighbourhood of cliffs undergoing rapid and extensive erosion is strong *presumptive* evidence in favour of the connection between the two, but it is not *conclusive* evidence any more than that recently brought forward by a comparison of analyses of the material existing in the cliffs of Yorkshire and the shore material in the Humber estuary and further south.

If the shingle banks off Spurn did not come from the north where did they come from? If from the north, and they could travel as far as Spurn, there appears no reason why sand and other detritus should not cross the Humber estuary and deposit material all along the Lincolnshire coast.

In a paper, "The Source of the Warp in the Humber," * Mr. W. H. Wheeler remarks that:—"At the Spurn lightship at the entrance to the Humber, the water is clear and bright, the samples taken at varying depths show no matter in suspension except a few grains of clean sand. The whole bed of the sea outside the Humber is covered with stones, clean sand, and shells." This no doubt applies to the condition of affairs in very fine calm weather. It is not at all common to find the water *clear* off the Yorkshire coast, and during storms, the whole sea for a mile or more from the shore is *thick with suspended matter*, so that the mere facts that samples of water, examined in exceptionally fine weather, contain only a few grains of sand, or that the bed of the sea is covered with stones, are no proofs that material does not travel in very great quantities at other times.

The positive statement that none of the Holderness material can possibly reach the Humber or the Wash seems to be based on the assumption that because a certain surface flow in one direction continues longer than another surface current in another, it is therefore

* Compare "Swatch of no ground" in H. Benest's Paper, "Submarine Gullies, River Outlets, etc.," *Geographical Journal*, October, 1899, vol. xiv., p. 410.

* "The Source of the Warp in the Humber." British Association Meeting, Glasgow, 1901. By W. H. Wheeler, M.Inst.C.E.

impossible for material to move in a direction opposite to that of the longer flow. The author of this article respectfully suggests that it is quite possible for material acted upon by the combined forces of wind, waves, and upper and *lower* currents, to be moved gradually along a coast line in a direction *contrary to that of the prevailing and most easily detected currents.*

A surface current might, for example, carry a particle for a distance of three miles in one direction, but, on sinking lower, the particle, coming under the influence of a deeper current, might be carried four miles in the opposite direction. In this instance the particle would have really moved over seven miles, and on reaching the bottom would be one mile from the starting point, and would have apparently proceeded that distance against the current.

Again the particle, having been carried for three miles in one direction, might sink as before and come under the influence of a deep current which would carry it four miles in the same direction; in this case we might assume that the surface current changed at the time the particle reached the lower stratum, and it would appear to the superficial observer that it should come back, but, being then under the influence of the deeper current, it would be seven miles from its starting point.

We have not yet learned enough about the deeper currents which accompany the changes of tides, and if such changes can be brought about in very deep water, it seems quite possible that the mud, sand, clay and shingle eroded from the Holderness coast may be first of all washed out into the deeper water lying between the cliffs and the Dogger Bank, and be then distributed again by strong deep currents or storms, or by a combination of both, and be washed up further down the coast. It appears to be a matter of conjecture at present, and it is rather dangerous, in our present state of ignorance as to the action of the deeper currents, to venture on *ex-cathedrâ* statements. One would like to see more experiments tried. For example, bags of various coloured material of different specific gravity might be spread on the sea bottom at various depths, also on the shores at mean sea level and low water mark. After some weeks the observations might be made by taking up specimens from different localities in the neighbourhood. For instance, supposing ten sacks of bright blue tile débris were "dumped" down in five fathoms off Withernsea, and that particles of this material were dredged up, six weeks later on, off the Spurn lightship, we should have very fair *proof* that the lower currents had carried and could carry material in 30 ft. of water in a southerly direction.

Probably it would be wiser to make the experiment on a larger scale. If, say, 1000 tons of some material—easily distinguishable but quite unknown on the Yorkshire coast—were thrown into the sea, and placed on the shore between Bridlington and Withernsea, this same material would, the author believes, be dredged up in minute but easily observed quantities not only off the Humber but off Gibraltar Point and in the Wash. It is in the conduct of experiments such as these that we may hope to clear away doubts; but unfortunately considerable expense is involved, and it is not easy to obtain grants or to secure the attention of those who should be interested when the proposal advanced is either scientific or bears the impress of novelty.

For the purpose of collecting and examining specimens from the sea bottom a simple form of "Grab"* has been designed which can readily be used from a boat and will bring to the surface half a cubic foot of shingle and sand at a time. The author believes that this grab will be found more handy than an ordinary dredge because it can be used without rowing the boat about and the *exact spot* below which the specimens are secured can be noted—which is not the case with the dredge.

Mr. A. R. Hunt has collected many of the statements of recognised authorities with respect to the power of deep sea currents and the movement of shingle, and it is certainly remarkable to what an extent the opinions differ.†

***Change in Configuration.*** When asked the question, "Does this country lose or gain land on the whole?" we must remember that we have yet a great deal to learn. It seems possible that, when taken over special years or short periods of time, the total loss by erosion may easily be greater than the gain by deposit; but that when adopting periods more approximating those in which geologists chiefly deal, the gains may closely approach the losses—*i.e.*, the outline of the country may change its form but the area may remain nearly the

* "The Utilization of Tidal and Wave Action." Feilden's Magazine, Sept. 1900.

† "The scientific Proceedings of the Royal Dublin Society," January 7th, 1885, by A. R. Hunt.

same. We have all seen maps showing, in deep shading, the areas filched from us by Father Neptune within historic times, and it would be interesting to come across maps showing such accretions as the 60,000 acres of Romney and adjacent marshes which have been added to the country within the same period.

Active loss and passive—but none the less certain—gain are going on simultaneously. We see the former in the falling cliffs and wasting beach, but we do not see the steady deposit of eroded material which is slowly raising the land in many places around the coast. As layer upon layer of sediment spreads itself over a big extent of sea bottom area—like the Wash, for example—the land rises until, in the end, over 100,000 acres may be added to the area of the country. Say, for example, that over a certain flat area of sea bottom, barely covered at low water, the deposit is known to be going on at the rate of a quarter of an inch in depth per annum, and that the range of tide is 10 ft. If nothing occurs to alter the rate of deposit, the water will become 1 ft. more shallow in forty-eight years, and before 500 years have passed that area will appear as dry land on the maps of the country.

Where, in Nature, a very considerable loss of material is observed to be continually taking place in the immediate neighbourhood of an equally remarkable accretion, it seems probable that the two are in some way connected, and that the phenomena merely indicate a change of position of the same material.* This is one of the author's reasons for believing that much of the enormous mass of material annually eroded from the Yorkshire coast finds its way to the Humber estuary, the Lincolnshire coast off Skegness, and to the Wash. To recapitulate; we observe that there is a large collection of shingle at Spurn Point which has travelled from the Holderness Cliffs, and it is fairly safe to assume that the currents—whether due to tide or wind, or a combination of the two—which are strong enough to carry this heavy material are also capable of carrying sand, mud and other finer material. Many of those who have considered this question have neglected to take into account the deeper currents and the question of alternate periods of repose and agitation during which particles may be moved down south, as it were, by stages.

The author cannot help feeling that Mr. Wheeler has perhaps taken too much for granted on insufficient evidence, and has rather jumped at his conclusions without first making sure of his facts.

* "Youghal Foreshore Protection Works and Deep Sea Erosion on the East Coast of England." Transactions of Inst.C.E. Ireland, 1903, Vol. xxx.

# Part III.

## THE COLLECTION, DISTRIBUTION AND ABSTRACTION OF NATURAL DEFENCES.

THE author believes he is correct in stating that, though there may be fewer disagreements between authorities at the present date than there were, say, twenty years ago, we have still a great deal to learn.

As regards *beaches*, we have to consider that the shingle is acted upon by two forces—the lateral drift or set of the tidal currents causing what is called the "trend" of the material, and the direct on-shore vertical forces of the breaking waves which force the shingle to form the highest "fulls" in the spring tides, and other smaller "fulls" at lower levels during other tides. In most of the shores which have come under the writer's observation the largest shingle seems to be thrown to the greatest height—some feet above high-water mark—the nodules decreasing in size until slightly above mean sea level, when they turn to gravel and finally join the firm sand which then slopes down at a very flat gradient, to low water mark.

Other shores are destitute of sand, and, like the Chesil Bank or Dungeness Point, slope down at a very steep angle into deep water; others again, like Cromer, Sheringham, Longbranch and Atlantic City are almost entirely composed of sand which will not as a rule lie at such a steep inclination as shingle.

The level of the highest "full" above H.W.O.S.T. varies very much in different localities, and is mainly dependent upon the depth and, therefore, *power* of the sea to force up the beach. Thus we find that at Chesil Bank, with a small range of tide—9 to 10 ft.—the very deep water outside exercises sufficient power to force the main "full" to a height of 30 or 40 ft. above sea level, whereas, at Glenbeigh, with a larger range of tide—12 to 13 ft.—the level of the highest "full" is not more than 6 ft. above H.W.O.S.T. This is accounted for by the comparative shallowness of Dingle Bay and the very gradual slope from the coast line to deep water.

At the Chesil Bank it will be observed that not only do the individual flints composing the bank diminish in size from the Bill towards the Dorsetshire coast, but that big flints lie all along on the top of the highest "full." At Glenbeigh the large flat red sand-stone slabs composing the beach lie at the highest points of the bank—at the very summit in fact—the smaller ones lying lower down until the level of the sand is reached.

The phenomenon of the largest stones being thrown to the highest points in a bank may be

accounted for by the power and dash of the on-shore wave during the flow of the tide being greater than that of the retreating wave. This on-shore wave will throw up stones of all sizes and drag back the smaller ones, because these, not having the weight of the bigger ones, are sucked back by the retreating wave, and this is more especially noticeable when the tide is ebbing, for then the "grabbing" or "sucking" out power of the wave appears to be greater than with the flow tide wave. If we place a heterogeneous mass of large and small nodules of stone mixed equally with sand and gravel on an incline, and pour a few buckets full of water gently over the whole, we shall find that all the sand and nearly all the gravel is washed down whilst the large stones remain a heap of clean shingle. This is what happens in nature; large and small stones mixed with sand and gravel are dashed up helter-skelter by the incoming wave, the heavy stones coming to rest almost immediately on or near the crest of the bank, whilst the smaller—down to the finest particles of sand—are washed to lower levels. This washing down is effected entirely by the force of gravity acting on the water in its return to find its level, and carrying with it particles which are deposited in proportion to their size near the toe of the bank.

It appears difficult to account for the various inclinations of shingle banks in different localities, and it would seem that these inclinations do not depend entirely upon the depth of water immediately off shore or upon the range of tide.

The question of the wholesale removal of foreshore material for building purposes or for ballast is one which is constantly being brought under the notice of those engaged in the protection of the coast line. The author has hardly ever been engaged on a shore where there was not some trouble from this cause, and he is now severely handicapped at Bray, near Dublin, where the foreshore owner is removing shingle and gravel at the rate of about 10,000 tons per annum.

At Glenbeigh the tenants of the estate have always drawn large quantities of sand for their farms, and it is unfortunate that they generally wish to take this useful backing from those very points on the shore where the sea is making its most determined advances.

At Youghal very little difficulty has been experienced, for people take sand, and those who require a few loads are amenable to reason, and take it from places where its abstraction will do no harm.

It is not unusual to find the authorities at seaside watering places in a state of considerable anxiety about the disappearance of beach from their foreshores, and yet to find that these same people are selling the beach for building or other purposes at a considerable profit. The idea is very prevalent that the next tide brings in as much as has been taken away, and that, therefore, it does not matter how many cartloads are abstracted.

On the 12th of June, 1902, the case of Hewson *v.* La Touche came before the Master of the Rolls in Dublin. The plaintiff is lessee of lands belonging to the defendant between Bray Head and Greystones Harbour, and had built a house on these lands close to the sea shore. He brought an action to restrain the defendant from carrying away the shingle and gravel which formed the natural barrier between the sea and the house. Some time previously, in November and December, rough weather had been experienced, and the waves had destroyed a large portion of the plaintiff's garden wall and garden, and had reached to within a few yards of the foundations of the house itself. The evidence showed that about 18,000 loads of shingle and gravel had been sold since 1900, and the author, who gave expert evidence for the plaintiff, pointed out that the heavy shingle banks lying immediately north of Greystones Harbour in front of the plaintiff's house were mainly derived from the eroded cliffs in the immediate vicinity, just as the similar shingle bank north of Bray Harbour is derived mainly from the cliffs between Killiney and Bray. The trend of all material appears to be from north to south, and the heavy portion of the material is caught on the northern sides of the harbour in both cases.

The shingle is limited in quantity, and when its volume is increased it is at the expense of the neighbouring cliffs. In proof of this statement we have only to examine the shingle above high water, or the sea bottom, the stones of which are found to be generally of the same character and formation as those at present in the cliffs and on the sea bed. In order to emphasise this point we may look to a few other beaches.

At Glenbeigh we have the old red sandstone formation with greenstone boulders of the glacial period fairly thickly strewn all over that portion of the district on the southern shore of Dingle Bay. Here we find the shingle to consist mainly

of old red sandstone and greenstone—the first named very largely predominating, probably to the extent of 9 to 1 or 10 to 1. It would be almost impossible to pick up a nodule of flint or granite.

Off Dalkey, where the rock formation is granite, it would be very hard to find sandstone shingle.

At Dover and places where the chalk and gravel flints are found it will not be easy to pick up granite or old red sandstone.

In Devonshire we find sandstone and in Cornwall granite predominating; in fact, in almost every case the predominating stone in the shingle accumulations is found in greatest quantities in the cliffs near by.

It has been shown that shingle does, *in exceptional circumstances*, travel for great distances in deep water, and that violent storms, acting in concert with certain sets of currents,

In the Section Fig. 10, taken in any direction through the middle of the hole C D, from which, say, one cubic yard of shingle has been removed, the thick line A B represents the surface of the

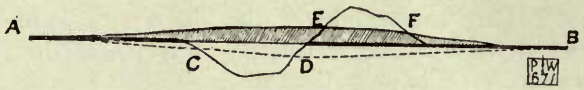



Fig. 10.

shingle previous to digging the hole, then the dotted line A C D B will indicate the beach surface after it has been subjected to the levelling influence of perhaps a single tide, *i.e.*,

1. If no fresh material has come in there will be a depression between the points A and B. To all appearance—as far as the eye can see—the hole may have disappeared, but the depression caused by the abstraction of the material will be there all the same, though only to be detected by careful levelling.

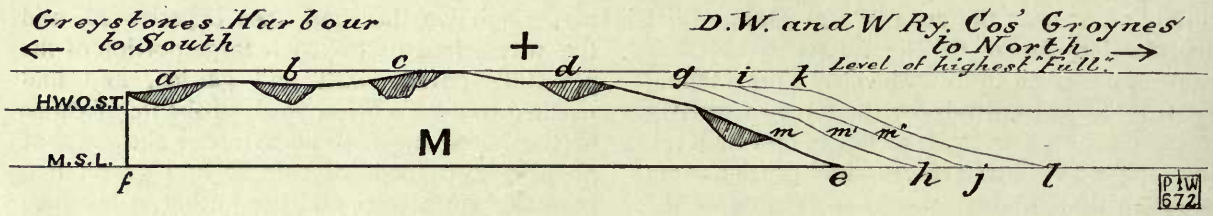



Fig. 11.

may bring in considerable accessions from distant places, but it will never do to rely on such accidents for the accumulation of material and protection of the coast line—*i.e.*, it would be most unwise to denude any shore of its beach on the chance of fresh supplies coming from a distance.

It has long been recognised that if a substantial bank of shingle can be induced to form and retain its place on the seaside of any more solid protective device such as an esplanade wall, two very great points are gained. If the shingle is thrown high enough the face of the wall escapes detrition, and of course its toe cannot be undermined. The object of all groyning is to bring about this natural protection, and to encourage the sea to do what we cannot do ourselves without the expenditure of large and often prohibitive sums of money.

With regard to the abstraction of shingle from any shore where it is acting as a barrier or protection from the sea the consideration of a very simple case may assist us in coming to a decision.

2. Now, for the sake of argument, we will suppose that fresh beach to the extent of one cubic yard comes in and fills up the hole. The shore will then be in the same condition as it was before the material was taken away, as the amount will have been replaced.
3. But supposing the hole C D had not been dug at all; then, if the fresh cubic yard E F came in, it would not be required to fill up the hole but would be capable of spreading out and thus adding to the volume of the shore, as shown by the upper line A E F B—the accretion being shaded in the Section.

From the above it will be seen that, whether fresh beach comes in or not, the digging and taking away of one cubic yard lessens the volume of the beach by that amount.

Again, let *a b c d e f* represent a longitudinal section of the beach between the top of shingle "full" and mean sea level to the north of Greystones Harbour, and let M represent the amount of shingle in the bank at any particular time. Fig. (11.)

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The position of the plaintiff's house, between the Harbour and the Dublin, Wicklow and Wexford Railway Company's Protection Works is roughly indicated by a cross. The trend of material from north to south will naturally have the effect of depositing in layers m, m′ and m″, and so working the beach accumulations in a northerly direction, and thus increasing the safety not only of the house, but also of the railway line.

If holes are dug as shown at *a b c d*, etc., they will have to be filled in again and the increments m m′ m″, etc., will either not form at all, or will be impeded in their growth to the extent of the material abstracted from the holes.

Properly speaking not a cartload of material should be removed from the shore, but when it comes to abstracting such wholesale quantities as 18,000 loads, about 10,000 cubic yards, it must be regarded as not only a serious menace to the house property, but also to the railway, which is thus deprived of all chance of benefiting by the spreading of the accretion in a northerly direction.

During the hearing of this case there occurred a somewhat amusing instance of a misunderstanding of technical terms. The learned K.C. who was conducting the defence construed the words "full" of beach to mean that the shore was full and could hold no more shingle and that, therefore, it did not matter how much his client took away. In order to emphasise his point he likened the beach to a cistern which when full of water could hold no more and that its "fullness" was in no way affected by using the overflow. In cross-examination by this learned counsel the author had some little difficulty in explaining that a beach *might* increase to any extent if allowed to do so—*e.g.* Dungeness Point or the whole of Romney Marsh—and that the term "full" merely referred to the ridges thrown up by the waves, such ridges varying in height according to the height of the waves, height of water, etc. In giving his judgment on the third day of the trial the Master of the Rolls refused to believe that the abstraction of such large masses of shingle right opposite the plaintiff's house had not contributed to the damage wrought in the winter and he granted the injunction sought.

It is a curious fact that earlier in the year a Board of Trade officer held an enquiry at Greystones and, as the result, an order prohibiting the removal of shingle from the whole shore between Bray Head and Greystones Harbour was issued only a few weeks before this injunction was granted in the Rolls Court. So that now this portion of the coast line is doubly protected from future depredation.

It is a pity that the Board of Trade prohibition was not made more far reaching, and that the whole coast line from Dublin to Wicklow was not included in the order. As matters stand no shore material may be removed between Killiney and a point north of Bray Harbour, but the foreshore owners are permitted to remove as much as they please between the above-named point to the north of Bray Harbour and the Harbour itself—a distance of only a few hundred feet—and between Greystones and Wicklow—a distance of over ten miles.

It is in the few hundred feet of shore line to the north of Bray Harbour where the worst depredations take place. Here lies a heavy shingle bank in the form of a talus, and throughout the year successions of carts may be seen drawing away both shingle, gravel and sand at the rate of about 200 tons per week. All that has been said above concerning Hewson *v.* La Touche applies with equal force to this short length of shore where the owner, Lord Meath, is so rapidly disposing of the beach to the detriment of the Dublin, Wicklow and Wexford Railway Company's line.

The argument probably used by the owner in this case is that the foreshore belongs to him and he has therefore the right to do as he pleases with it; that the Railway Company knew, or ought to have known, at the time the line was being constructed, of the existence of this right, and that, if they thought it prejudicial to their interest, they should have taken a more inland course and thus avoided the chance of future difficulties.

This argument may be well enough in its way, but the author believes that it is a legal maxim that you may not benefit yourself or your property if, in doing so, you materially damage your neighbour or his property. As an example. If A builds a long solid masonry groyne or jetty for the purpose of collecting material or otherwise improving or protecting his line of foreshore, and it can be proved that the structure is causing great damage to B's adjacent foreshore, then A can be compelled to remove his groyne.

Or to take another example: A owns a house in the middle of a row. He cannot on the plea of ownership pull that house down and root up

the foundations without making such provisions as shall secure his neighbours on each side from any danger of a collapse of their dwellings. At Bray the case is very similar, for the foreshore owner says in effect :—

"The shingle belongs to me, it is lying on my property, and I can keep it or sell it just as I please."

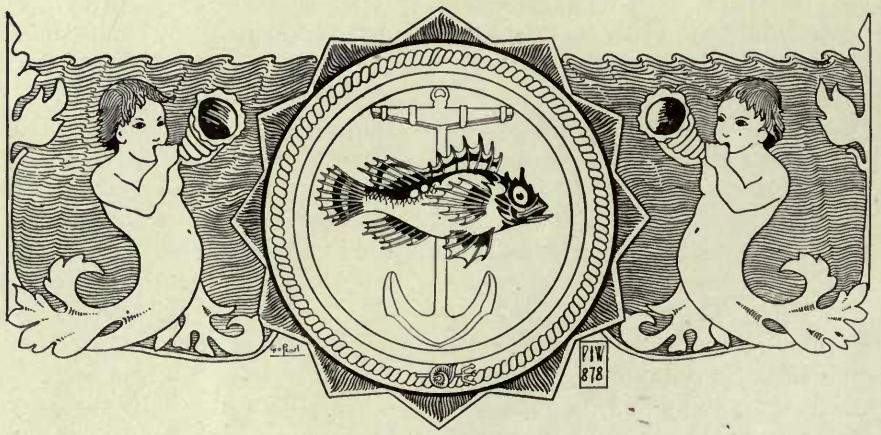
The answer to this is :—"If you take away this material, which is the only barrier between the sea and your neighbour's property, you are practically rooting up his foundations and seriously jeopardising the safety of an important public railway line."

For many years past there appears to have been a very great difference of opinion amongst the Judges as to the law of support, and reference should be made to the cases of "Kempton *v.* Butler," and "Latimer *v.* Official Corporation Society." Probably the most important case is that of "Dalton *v.* Angus," which was taken to the House of Lords in 1881. Their Lordships then decided that the owner of an ancient building has a right of action against the owner of lands adjoining, if he disturbs his land so as to take away the lateral support previously afforded by that land, and they gave decision in favour of plaintiff. This practically reverses the law, as previously understood, and must be taken to be the law now.*

From the building contractor's point of view stopping this supply of clean sharp gravel—so admirable for concrete—would in many cases be little short of a disaster, and it has been said that even the railway companies have in many instances made goodly sums in freightage of shingle and gravel which should have been left on the shore for the protection of the line.

When we consider that 10,000 cubic yards of beach—quite a common amount to be taken from a foreshore in the course of a year—represents a bank 15 ft. high, 30 ft. wide, and 600 ft. long, and that, in most cases, this can only be replaced by material eroded from neighbouring cliffs, and what is carried in from deep water during storms, we can arrive at some idea of the trials of a foreshore engineer who is endeavouring to collect, arrange, and retain material for the *protection* of the coast line. In such cases one almost feels that the rapacity of Man is leagued with the destructive forces of Nature to defeat the ends of Science.

* "Transactions of the Institution of Civil Engineers of Ireland," xxviii., 158.



# Part IV.

## PROTECTIVE MEASURES AND PERMISSIBLE EXPENDITURE.

SCIENCE often owes much to enthusiasm, and the persistent and even fanatical following up of a special line of thought or argument will sometimes open up side issues resulting in very important discoveries. We should therefore not be too ready to damp the ardour of the enthusiast because we cannot quite follow him—the leap he takes may be *in the right direction*, though to many of us it may seem to be taken in the dark.

The author has had excellent opportunities of carefully watching the effects produced by different kinds of groynes in situations where the conditions as regards range of tide, exposure, nature of material, etc., have differed widely, and, as a result of these observations, he believes that on most shores low groynes should be relied on for the collection and retention of material because their action is gradual and certain and not productive of scour. Experience also shows that these groynes act far better in some places than they do in others, though they invariably have a beneficial effect. The idea of carrying the groyne well down to low water mark is an excellent one because the greatest visible area—over which travelling material is moving—is affected and consequently the greatest chance is offered for adding to the accumulation of natural protection. Having first tried slanting groynes between high water mark and mean sea level, and then having had the advantage of applying the Case system of low groyning to shores presenting especial difficulties, the author became an ardent supporter of the low groynes which he still advocates in preference to all others.

It has occurred to him, however, that the low groynes, though extending to the lowest possible point on the visible shore, do not extend far enough to influence the erosion which is steadily going on in many places, in deeper water outside their influence, and it is mainly in consequence of following up the theory and practice of low groyning that he has been able to arrive at the conclusion that, where deep sea erosion is steadily progressing and soft material extends to depths far below low water level, protective measures can only be regarded as palliative.

From what has been said in a previous article of the Bray shore it will be gathered that the advance of low water mark is immediately traceable to erosion taking place below low water

level, probably accentuated by the scour from the high sea wall, and that the toe of the wall has been protected by the action of the low groynes which have, so to speak, kept that important portion of the shore clothed in shingle.

Putting two and two together the author believes that, in very many cases, a judicious combination of slanting groyne and low groyne may be highly advantageous to shores which are undergoing rapid erosion because such a system would be most likely to keep Nature's protection, or clothing of sand and shingle, in place.

There are occasions when a wall may possibly be far too expensive, or altogether undesirable on account of insecure foundations, and the author has suggested a form of curved slanting groyne, which he believes embodies the advantages of both systems. The curve, joining the two, offers no direct opposition to the action of waves or currents and softens down the angle which would otherwise exist. Our aim should be to coax or "wheedle" the turbulent forces with which we have to deal so that they will do our bidding.

The action of the slanting portion of the groyne differs from the action of the Case groynes, which act on the lateral currents by slowing them down, and causing a deposit of material which would otherwise pass away. The curved slanting groynes rely almost entirely on the agency of the waves, and trap and detain shingle which is thrown over from windward to lee.

It is instructive to spend a few hours in watching the result of a dead on-shore gale on slanting groynes. If there is much travelling beach it will be observed that the shingle—often consisting of heavy stones—is bodily carried over the top of the groynes and retained on the lee side, where it is required for the formation of the "full." This retention is due to the circumstance that the slanting groynes, running diagonally up the beach, are inclined at a *much flatter gradient than those groynes running at right angles to the coast-line*, and, therefore, the retreating volume of water which causes the scour has less power to carry away the deposited shingle. On the same principle a very rapid mountain torrent will carry down huge boulders, which would rest peacefully for ever at the bottom of the same river when it emerges into flatter lands and winds amongst the lower valleys.

* The slanting groynes recommended form a continuation of the Case groynes from mean sea level up to high water mark, and they are constructed on much the same simple principles, but the timber has to be of heavier scantling because of the pounding action of the sea in rough weather. Here it may be observed that, in selecting our timber we must be guided by the position it is to occupy on the shore as well as by the size and quality of the shingle composing the beach.

Experience seems to show that, when acting on timber—especially vertical piles—the sawing action of sandstones is worse than that of rounded flints, though the latter may have a more erosive effect on the faces of sea walls. Where piles have been driven anywhere in the neighbourhood of high water mark, in localities where there is a heavy travel of beach, it will often pay to protect the *windward piles*, at the portions where they are most subjected to this sawing action of the shingle, by angle iron, or, better still, by nailing on planks, which can be renewed when worn through. This may seem a small point, but it is one which should receive attention. The life of the windward piles may be doubled or trebled by attention to this detail, and much expense saved in repairs and general maintenance.

The construction and application of these slanting groynes were very fully described in a paper read to the † Institution of Civil Engineers in Ireland, and shortly afterwards the author received communications from gentlemen who had read his paper objecting to these groynes as being erected at high water mark, and therefore bound to create scour. The arguments in the objections were not of a very scientific nature and amounted to this:—"The slanting groynes are near high water mark, and therefore must be condemned."

Feeling that he had not made his meaning sufficiently clear the author then prepared a second short paper, in which he endeavoured still further to explain and elucidate the question.

The following paragraphs from this second paper are here quoted:—

"It will be conceded that there must always be some obstruction at high water mark. The line of demarcation or boundary between the sea and land always exists, whether in the form of a sand dune, a shingle bank, esplanade wall, line of sheet piling, or stepped breastwork wall.

* *Fielden's Magazine*, December, 1901.

† "Transactions of the Institution of Civil Engineers of Ireland."—Vol. xxviii., 1902, pp. 146-150.

"If, therefore, it can be shown that a particular form of high water protection answers the purpose of collecting and retaining shingle in certain situations, there can be no reason in objecting to it merely on account of its name. The fact is that, as strong advocates of the Case system of low groynes, and equally strong opponents of the ordinarily accepted high groynes, as erected at Hastings, Brighton, and elsewhere, we are, not perhaps unnaturally, apt to regard with disfavour anything in the nature of a groyne anywhere near high water mark.

"As regards the form of slanting groynes suggested by the author, the idea was to use them as accumulators or traps for the shingle at points on the shore where the Case groynes do not reach but which, nevertheless, have to be protected. The elliptical concrete wall, or similarly designed embankment of timber, has been successfully applied in conjunction with the Case groynes, but a close examination will reveal the fact that the slanting groyne is in reality a modification of the stepped wall, each step of which touches a point on the curved and slanting groyne. The protection afforded by the slanting groyne may not be so effective as that given by the stepped wall, but where there is a heavy travel of beach and a long line of coast to be protected, and limited means at the disposal of the engineer, it is suggested as a valuable auxiliary.

"The idea of using slanting groynes is not by any means new, so that the author disclaims any title to originality under this heading. There appears, however, to be some indication of novelty in the idea of a curved groyne gradually working up from a low groyne until it has reached the limit of high water mark, and the advantages of such a groyne may be best worked out theoretically by first of all considering some of the most important phenomena and conditions obtaining on the generality of shores.

"It will be at once conceded that the steepest line of descent on any shore is found by taking a section of the shore at right angles to the coast line. It follows then, that when originally constructed, all groynes running at right angles to the coast line have, on either side, the steepest possible gradient on that portion of the shore.

"It will probably be also admitted that, if the groyne be run out in any other direction whatever on either side, the gradient will be less steep, because the line will run diagonally up and down the beach. The maximum of steepness is shown by the sectional line at right angles to the coast line, all other lines gradually diminishing in steepness from 0° up to 90°, when the minimum is reached at dead level with the original point of starting.

"It can also be easily proved by elementary mechanics that bodies more readily slide down steep inclines than they do down inclines which are not so steep, and that, where the action of water is concerned, heavy boulders and shingle of all sizes are readily moved in rapid rivers, and that they are not moved at all, or only very slightly, in sluggish rivers.

"Following up this line of reasoning, we arrive in a very few steps at the conclusion that the important point is *the steepness of the gradient*, and that where scouring action is to take place, it will, *ceteris paribus*, be worse on the lee side of those groynes which run down the steepest gradient.

"It can also be demonstrated that the less steep the gradient the longer it takes the water to run off by filtration or percolation, or by running down the lee side of the groyne, and that, therefore, material of all kind has a better chance of being retained where it is wanted.

"It can also be readily shown that those proposed groynes (being constructed as described in the author's recent paper and read to the Institution on January 9th) are not of the nature of solid immovable structures, and can always be lowered or raised to meet *the circumstances of the case at any moment*, and that, therefore, they must not be included in the list of dangerous solid obstacles at high water mark."

To turn to the practical aspect of the matter. In 1896, during the author's absence from Ireland, a couple of box groynes were run out at right angles to the shore line at a portion of the Glenbeigh coast, where the cliffs were undergoing very rapid erosion. These groynes not only failed to collect material but caused the formation of bays or indentations of the cliff on either side, and, as in the case of other shores where high groynes are to be found, scours occurred on either side.

In 1898 the author erected three slanting groynes of a more solid form of construction (shortly described in his paper of January 9th, 1901). There was practically no shingle at all at the toe of the cliff when these groynes were completed in the summer of 1898. Repeated

observation showed that shingle was continually thrown over and retained on the lee side of these three groynes, and that the improvement has been continued, and is still continued is clearly demonstrated by the existence of a heavy bank of shingle effectually protecting the toe of the cliff, which is now grassing over in many places. This shingle was not there in 1898; it is there to-day, and this actual fact should go far towards backing up the author's opinion that slanting groynes will, in certain situations, catch and satisfactorily retain shingle.

We have to admit that it is common sense, backed by technical knowledge and experience, which carries us through the most serious engineering difficulties.

In the case before us we have a set of slanting groynes of very rough and ready construction, and most imperfect in design, and yet it is shown that they have been instrumental in safeguarding a portion of the coast.

Common sense points to the probability that similar groynes more scientifically designed will be even more effective, and the author in designing these partly curved slanting groynes has kept carefully before him the points which have seemed of greatest importance, viz.: trapping and retaining of shingle; reduction of scouring action; rapidity of lowering and heightening; simplicity of design and economy.

If we build a bridge, or a retaining wall, or a house, there is a reasonable hope that, given immunity from earthquakes, waterspouts, or foreign invasion, the work will at any rate outlive the present generation. But with sea coast protection works this is by no means the case, for the engineer, often cramped in his designs and estimates through the limited means at the disposal of his clients, finds he has to fight against a most relentless foe with very indifferent weapons. In short, he has not to carry out what he feels certain is necessary to insure protection, but to make the best job he can of it with very inadequate means.

The author has been for so long advocating the claims of the "Case System" as being better than any other, that it is hardly necessary for him to disclaim any intention of supplanting that system, which seems to him to stand alone in its originality of conception. What he wishes to do—and his humble efforts have been entirely in this direction, and with this object in view—is to think out and devise some method which, without clashing in any way with his late friend's invention, may be profitably used as an auxiliary in certain situations.

Some advantages of a combination of low groynes with slanting groynes appear to be:—

1. The diversion shorewards of material travelling between low water and mean sea level by the low groynes, this action depending mainly on lateral currents.
2. The catching and retaining of beach by the slanting groynes which need never cause scour, because they can be regulated to meet the requirements of the case almost as easily as the low groynes.
3. The accumulation of beach takes place both on the windward and lee sides of the slanting groynes.
4. The slanting portion of the groynes may, in many places, take the place of walls.
5. The low cost of these slanting groynes is in their favour.

Portions of the above have appeared elsewhere, notably in the Transactions of the Civil Engineers of Ireland, and as nothing would be gained by putting his unchanged opinions into other words the author has made very few alterations.

Drawing attention to this new aspect of the foreshore problem is merely tapping one of the sources of information which abound in such profusion throughout nature. Abstruse subjects are often illuminated by an honest and careful examination of facts, though the light itself may come from an unexpected quarter. Unfortunately in sea problems the difficulty of obtaining sufficient data, and agreeing about the facts on which to argue, present serious obstacles to profitable discussion.

Then again every new theory which, if correct, must alter practice, will inevitably have to contend against a certain amount of prejudice. When, for generations, a particular line of thought has predominated with respect to the point of view from which certain natural phenomena should be regarded, when public opinion and expert opinion have alike become stereotyped or fossilised, any departure from this beaten line of thought comes as a rude shock.

We naturally, and probably correctly, regard the middle ages, or dark ages, as the epoch most favourable to prejudice, but it is not so very long since the old coachman regarded the steam engine as a monstrous impossibility—prejudice

was alive, though possibly moribund, in the nineteenth century.

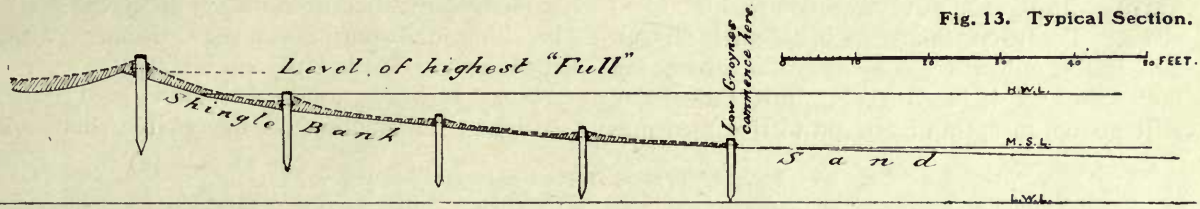
The author remembers some years ago showing a rapidly disappearing coast line to a gentleman who, after a short inspection of waves and cliff, said cheerfully, "This is very easy, why don't you build a wall?" Here prejudice, prejudice in favour of building walls, came out. As a matter of fact the erection of a wall at that spot would have been not only costly and useless, but would have increased the rate of erosion very considerably. The advice to "build a wall" was given in all good faith, but with a complete want of knowledge of the conditions obtaining. Ignorance, that constant henchman of prejudice, was no doubt greatly responsible for the advice which was further backed up by a sketchy and undefined idea that waves should not be unaccompanied by walls.

Whatever sets of conditions have to be dealt with, all the arguments in the world won't alter their existence. What we have to do is to find out all we can about them, and then take such practical measures as will secure the best results in the circumstances, *i.e.*, having regard to the value of the land, length of time the protective measures are expected to last, and the means at the disposal of the owners.

The author has very little doubt that in many situations rows of sheet piling, running parallel with the coast line and driven between the level of highest "full" and mean sea level, might be adopted with advantage in connection with a system of low groynes such as that designed by the late Mr. Edward Case. The effect would be much the same as that produced by the slanting groyne combination previously described, only the construction would be rather more costly on account of the number of parallel rows required. This arrangement of sheet piling and low groynes is very similar to that of a stepped wall and low groynes, only the horizontal distances between the rows would be filled in by shingle thrown over and retained even more effectually than in the case of the slanting groynes. (Fig. 13.)

The methods here recommended would be applicable to most shores needing protection, and the author especially advocates their adoption in cases where there is little chance of permanently saving the situation, but where the evil day may be put off by collecting sand or shingle which covers and protects the erodible shore material for several months in the year. An instance of this class of protection is shown at Bray, previously alluded to in these pages, where the Case groynes have been instrumental in collecting large quantities of sand during the summer months in a situation where sand was formerly unknown. Whilst this sand covers the shore erosion cannot take place over the area so covered, though it unfortunately continues to go on at lower levels, and in time undermines both the subjacent marl and its mantle of sand.

**Fig. 13. Typical Section.**




Alternative method; sheet piling, parallel with coast line, used in conjunction with low groynes from mean sea level to low water level, these latter being at right angles to the sheet piling.

In the hope that it may add somewhat to the interest of these articles, the author here gives a list of various coast lines with which he is acquainted. On most of these he has been employed for making reports, estimates, plans, etc., whilst in several he has been in charge of the works for many years past. The list is fairly comprehensive, and includes places where the circumstances and conditions differ very widely. In each case a very short description of the situation and requirements is given, together with suggestions as to the most economical methods to be adopted in the future.

***Arbroath, Scotland.*** The authorities were anxious to improve the seaboard of the Victoria Park near the town by inducing sand to accumulate where at present only unsightly rocks are to be seen. There is no danger from erosion or even exceptional high tides and gales; it is merely a question of improvement, and this could easily be effected by the erection of a few low groynes, which would catch and retain the travelling sand.

***Musselburgh, Scotland.*** Occasional trouble is experienced in the neighbourhood of the golf links. There are no evidences

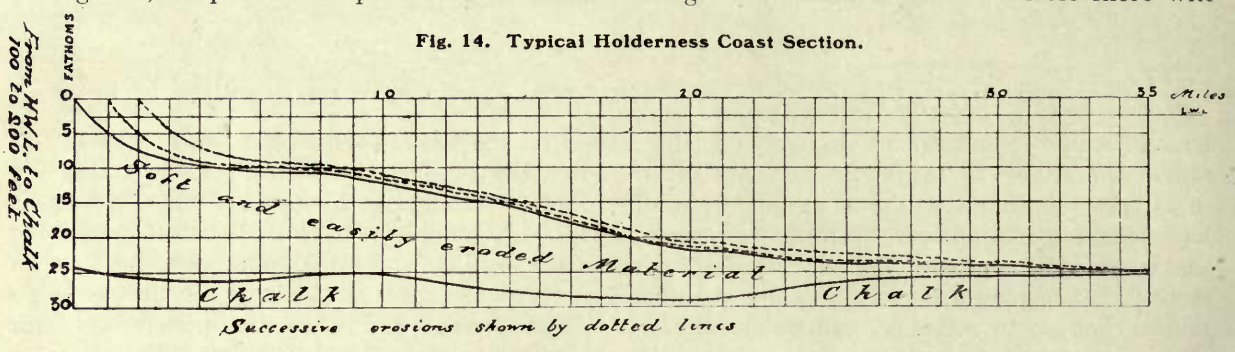
of very marked erosion, and a vast improvement might be effected by the construction of low groynes as there is a considerable travel of sand.

***Holderness, Yorkshire.***

As most people are aware, the steady and continuous incursions of the sea on this coast, between Bridlington and Spurn point, has been going on for many centuries, and the changes may be said to have been fairly accurately recorded both on the coast line and the Humber estuary during the past three or four hundred years. Tradition takes us back still further, and, if the author's theory as to the advance of low water mark has anything in it, the erosion will go on, in spite of our protective measures required for protective structures, appeal to those owners whose interests are further inland, but these reply with considerable force that as the sea cannot, at its present rate of progress, reach them for two or three hundred years, they would prefer to keep their money in their pockets. The situation is vastly different where large stretches of low-lying land may be placed at the mercy of the sea by the breaking down of coast defences—*e.g.*, Essex flats, Wexford slobs, or Romney and adjacent marshes—there the sea, on breaking in, at once floods the entire area, which it cannot do on the Holderness coast.

Since, however, no protective devices at present designed for erection on the visible shore will

**Fig. 14. Typical Holderness Coast Section.**



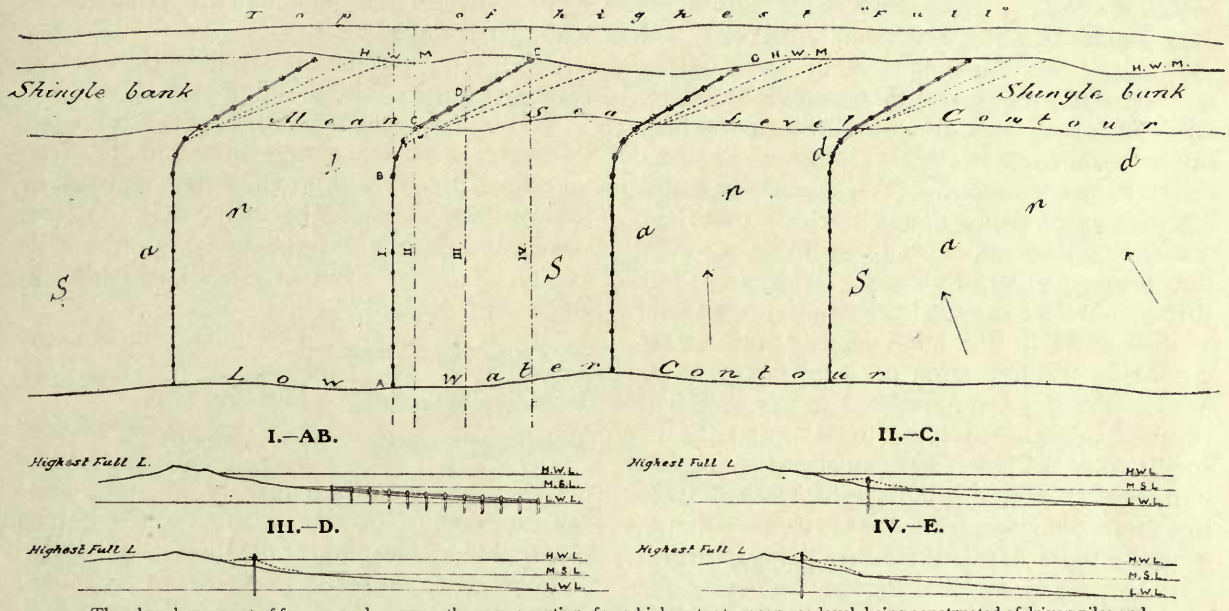

on the visible shore, until the waves again beat on the far inland chalk cliffs, as it may be conjectured they did prior to the glacial deposit of which the lands of Holderness are composed. The history of our coast line is not without instances of a retrograde movement on the part of the sea, and it is of course possible that influences which we cannot at present understand or foresee may turn the present annual loss into a gain. All we can do now is to study the past and present rates of erosion, the causes of that erosion, and design our protective devices so as to retard the sea's advance as far as possible at the lowest cost. Sections taken from the coast line in a north-easterly direction, Fig. 14, show a remarkable uniformity. All down the forty or fifty miles of coast the 5-fathom line is formed at a mile from the shore, and this, taken in conjunction with the other evidences previously adduced, points to a steady eating away of the coast both above and below low water level, probably as far as the 10-fathom line six to eight miles out to sea. In this particular case we have high-lying agricultural land disappearing at the rate of, say, 6 ft. to 10 ft. a year. The owners on the immediate sea front, being unable to afford the large suggested sums stay that erosion which the author believes he has proved to be going on below low water level, it is perhaps as well that further waste of money is unlikely to be indulged in. There is, of course, the question of the towns, but here again the elaborate and costly nature of our protective devices will not alter the soft and erodible nature of the material on which we build, and, after all our outlay, we can only hope to secure, for a very limited number of years, a small island on which our town stands. The island, formed by the sea's action in washing away the coast on either side and all round the protected town, will only be maintained at very great expense and must in its turn also disappear as the deeper water continues to advance. In the case of Holderness it is very doubtful whether the palliative effects of a system of groyning would be sufficiently marked to justify the outlay. To put it more clearly, if we could reduce the annual erosion from 8 ft. to 3 ft., would the value of that strip of 5 ft. saved be sufficient to cover and pay interest on the expenditure? If such protective devices could be secured with a life of twenty years we should be able to save a strip of land 100 ft. wide at the end of that time. That is to say we should have saved about twelve

acres of land per mile of frontage and, taking the outside rent at £3 per acre, we should have but £36 income to pay for our mile of protective measures. Now the most moderate estimate for protective works would hardly be lower than £3000 per mile, and the interest on this sum would hardly be less than £120, and we should thus be out of pocket £84 per annum, so that on the figures here roughly given, or any approximation thereto, it is clearly cheaper to let the agricultural land go than to attempt to save it.

Norfolk, over 100,000 acres will probably be added to the area of the country before the end of next century. No protective measures are needed here, as nature is doing by sand deposit what she is doing by shingle accumulation at Dungeness Point in Kent, viz., adding to the extent of the country's area.

***Cromer, Norfolk.*** For many years past cliff erosion, very similar to that which is going on along the Yorkshire coast, has been giving much trouble both opposite the town and in the neighbourhood of the golf links.

**Fig. 12. Curved Slanting Groynes.—Typical Plan of Shore.**




The plan shows a set of four curved groynes, the upper portion, from high water to mean sea level, being constructed of driven piles and substantial but easily adjusted planking. This portion is slanted so that the most destructive wind shall meet the groyne almost at right angles. A short length of curved groyne joins the upper portion to the lower groyne, which, for reasons which are sufficiently apparent, is constructed of timber of much lighter scantling.

The dotted lines indicate various angles at which the slanting groynes may be constructed to suit various conditions.

Sections I., II., III. and IV., taken at right angles to the coast line through the frontage of groyne A.B.C.D.E., speak for themselves; the vertical scale is exaggerated. In the last three, the accumulations both to windward and lee are indicated by the dotted lines. The more pronounced the slant, as a rule, the more rapid the accumulation.

***Skegness, Lincolnshire.*** Here we are furnished with an example of the land encroaching on the sea. Sand dunes are forming all along the coast, and Gibralta Point, the most eastern point in Lincolnshire, stretches far away into the North Sea; indeed, at low spring tides the horizontal distance between high and low water marks may now be measured in miles instead of yards or feet. Much of the vast deposit here accumulating probably comes from the disappearing cliffs of Holderness. Even when the tide is only moderately low an inspection from any coign of vantage at Gibralta Point reveals tens of thousands of acres of land stretching away to the east and the south-east in the Wash, where, between Lincolnshire and Norfolk, over 100,000 acres will probably be added to the area of the country before the end of next century. No protective measures are needed here, as nature is doing by sand deposit what she is doing by shingle accumulation at Dungeness Point in Kent, viz., adding to the extent of the country's area.

***Cromer, Norfolk.*** For many years past cliff erosion, very similar to that which is going on along the Yorkshire coast, has been giving much trouble both opposite the town and in the neighbourhood of the golf links. Here the worst erosion probably goes on below low water level and all protective devices must be regarded as palliative.

***Sheringham, Norfolk.*** An instructive object lesson is here shown in the advantages which may be secured by low groynes. The portion immediately opposite the town is not groyned, and the sea continues to advance, whilst both to the east and west sand accumulations are well maintained by the groynes which have for years past stopped the sea's advance.

***Southwold, Suffolk.*** A difficult shore, where sheet piling, concrete walls and low groynes have all been tried with varying success. The beach is mainly of

shingle, which lies at a steep angle, and it is felt that the low groynes have not produced such good results here as they have elsewhere.

***Clacton-on-Sea, Essex.*** Those interested in this growing little watering-place have been put to great expense both in sheet piling and groyning. The clay is soft and easily washed away even by the rains. One of the chief troubles here appears to be the tendency of the sea to outflank any walls, etc., however far they may be extended from the town.

***Atlantic City, New Jersey, U.S.A.*** Here we have a very remarkable example of American enterprise and confidence. Only half a century ago only two or three houses stood on the long spit of sand which to-day supports fifty big hotels and accommodates hundreds of thousands of visitors during the summer months. The site is certainly not one which would at first sight commend itself as a desirable one from the investors' point of view, for there can be but little doubt that the whole place might easily be washed away by the impingement of a current caused by the formation of some heavy sand-bank in the vicinity. As Mr. Francis L. Pruyn says:—"From Sandy Hook to Atlantic City the condition of the beach seems to be more or less unstable. The sand is built up or washed away in an uncertain manner, so that to locate cottages near the shore is often a rather dangerous proceeding. At Long Branch the sea has made almost steady encroachment, and valuable hotels and cottages have frequently been endangered, necessitating the costly procedure of moving the structures further back from the ocean."

In November, 1901, the writer visited Longport, at the southern extremity of Atlantic City, and was much interested in Mr. M. S. McCullough's protection works. This was just at the time of the severe gales, when much of the "Board Walk" in Atlantic City was damaged and about 100 ft. depth of Mr. McCullough's frontage at Longport had been carried away.* At present it cannot be said that the sea is making a "dead set" on any portion of Atlantic City, though occasional visitations do a great deal of damage, which might be lessened by the application of a system of low groynes, as suggested.

* "Protection and Improvement of Foreshores." American Society of Civil Engineers. Vols. XXVIII., No. 6, 1902, and L., p. 66, 1903.

***Long Branch, N.J., U.S.A.*** Here the trend is northward, in the direction of Sandy Hook, the material eroded from Long Branch where it is much wanted being deposited where it is not wanted. An extensive system of low groyning would be of the greatest possible service to this shore, and would retain in place tens of thousands of tons of sand which is now lost.

***New Brighton, N.Y., U.S.A.*** The conditions here are not so favourable as they are at Long Branch and Atlantic City, but the judicious application of the Case system would undoubtedly be attended with good results.

***Hastings, Sussex.*** The scouring action, set up by the high groynes which at present disfigure and mutilate the shore, is steadily aiding the sea in its efforts to encroach. If these groynes were replaced by low groynes it would be found that the scour would disappear and the shingle bank would lie evenly along the toe of the wall, as it does at Bray.

***St. Leonards, Sussex.*** The same remarks apply here.

***Brighton, Sussex.*** And here also.

***Worthing, Sussex.*** Low groynes were tried here about three years ago, but on such a limited scale that they could not be expected to bring about much improvement. After a few months the three short groynes —which had not been extended to half their proper length—were cut down: had they been given a proper chance they would have converted the shore from a muddy, dirty place into a fine dry playground for children.

***Eastbourne, Sussex.*** Here again the low groynes were never given a fair trial, though it must be admitted that they did wonderfully well considering how they were interfered with by the high groynes.

***Deal, Kent.*** The travelling shingle here has been retained and maintained at a satisfactory slope for many years by the low groynes; one of the chief troubles was the action of the "*teredo navalis*," or ship worm, which attacked the timber with disastrous results.

***Dover, Kent.*** The shingle on this beach has for years past been known to alternately accumulate and disappear from certain portions of the frontage with

remarkable rapidity. The high groynes have, again and again, demonstrated their capabilities of bringing about extensive scours. Now that the harbour works are getting on it is expected that a marked change will be observed. The breakwater will probably prevent any heavy sea from visiting the shore and the whole of the conditions which have hitherto prevailed will be entirely changed when the great work is finished.

***St. Margaret's Bay, Kent.*** This pretty little watering-place has suffered severely of late years. The frontage is of very small extent and rather difficult to protect on account of the sudden drop into deep water which occurs at a distance of less than half a mile from the shore. The low groynes were tried some years ago on a very limited scale and without any satisfactory result.

***Weymouth, Dorset.*** Some years ago it was decided to protect the Preston beach with Case groynes between the town and the coastguard station. This work has been satisfactorily carried out.

***Bray, Co. Dublin.*** This shore having been previously described it is only necessary to state here that it now affords an object lesson of what low groynes will do even in the most exceptionally difficult and unfavourable conditions.

***Glenbeigh, Co. Kerry.*** In continuation of remarks on this place it may be mentioned that the author has had to report on several occasions and that in his last report dated March 24th, 1903, he concludes a lengthy and careful investigation of the conditions, *pros* and *cons*, ways and means, etc., by saying :—

"Is there any remedy? The slanting groynes and Case groynes being the remedies by which it was thought the sea might be induced to build up the shore and so afford a permanent protection at small cost, having failed to do all it was hoped they might do, we return to a consideration of the conditions obtaining and problems involved in the hope of being able to advise as to the wisest course to pursue in the future—having due regard to the *value* of the property at stake and the *financial resources of the Estate*. . . . In the neighbourhood of the place where the breach will probably occur we have a distance of over 2000 feet to protect and nothing better than sand and bog for a foundation, so that a sea-wall, however good and expensive, would in time be undermined and disappear as I have seen scores of walls disappear. You may take it as a fact that no wall *within the means of the Estate* would stand a single storm, so that that means of protection may be put on one side as altogether out of the question. High groynes would be worse than useless as they would accelerate the disaster. Low groynes have certainly done some good, but in view of the dead set of the sea, the scouring away of collected sand and the destruction for the second time of one of the groynes, I cannot recommend the expenditure of any more money upon these groynes. . . . .

. . . "It is very much against the grain thus advocating a policy of inaction, but I am merely doing in this case what I have done for other clients, viz., endeavouring to take into consideration all the circumstances and to give advice accordingly. The situation is so full of difficulties *from a purely Engineering point of view* that even if you placed £10,000 at my disposal I should have grave doubts about sanctioning the expenditure of more than a few hundreds in temporary breastworks and strengthening of one of the slanting groynes."

***Youghal, Co. Cork.*** Here in 1899 the sea broke in and flooded over 600 acres of land and seriously jeopardised the safety of the G.S. & W. Ry. Co.'s line near the Youghal terminus. It was some time before the work was started, and the delay was chiefly caused by the difficulty in getting the various interested parties to agree. By the time they did agree matters had gone rather far, and when the breach had to be closed it was close on 500 ft. across, and the tides rushed in and out with considerable force. Two sluices and over twenty long low groynes were put in, and the work has turned out very well, all things considered.

Amongst the other shores with which the author is well acquainted may be mentioned ARDMORE, Co. Waterford; DUNGARVAN, Co. Waterford; TRAMORE, Co. Waterford; TACUMSHIN, Co. Wexford; BARNAGHERA and PORTRAINE, Co. Dublin; WICKLOW and GREYSTONES, Co. Wicklow; WATERVILLE, DARRYNANE and BARROW, Co. Kerry; all of which present interesting features.

It will be gathered, from what has gone before, that "soft" shores—*i.e.*, shores where an easily eroded material lies beneath the surface—may be roughly divided into three classes :—

1. Where erosion is marked and continuous

from year to year, *e.g.*, Holderness, Glenbeigh, Bray.

2. Where erosion only takes place on special occasions, such as high tides, storms, etc., *e.g.*, Youghal, Atlantic City.
3. Where the sea is retreating from the land, *e.g.*, Skegness, the Wash, and Dungeness.

As will be readily surmised by those who have perused these articles, there are many instances in which great economy may be effected by designing protective measures with the view of staving off the evil day as long as possible and at the same time minimising the ultimate and inevitable loss. If a line of coast cannot be saved because of the erosion going on below low water level, the next best thing to do is to save as much as possible on the loss, and this can be best effected by the use of low groynes which collect sand and shingle and retain them during certain months. Some sort of wall, embankment or line of sheeting will, in most cases, be necessary with the groynes, and it will be well to design both with a view to the probable advance of the sea and the loss which will occur when the work is destroyed.

The author believes that the theory he has endeavoured to explain in the preceding pages presents a new aspect of the foreshore protection question. It is of course possible that he may be out in certain matters of detail, but he believes that the general principles enunciated are well founded and borne out by actual experience.

In any case the mere effort to look into and discuss these highly important questions from a standpoint different to that usually taken up, cannot but be beneficial and may possibly lead to fresh discoveries in a branch of engineering in which no one will deny we all have a great deal to learn.

---

Mr. R. G. Allanson-Winn has for several years past been identified with sea coast protection works, and since 1897 has given up most of his time to the study of intricate problems connected with foreshore erosion and land reclamation. Mr. Winn was educated at Westminster and at Trinity College, Cambridge, where he took Mathematical Honours. He afterwards studied Engineering at Kings' College, London, under Professor Henry Robinson. His earliest practical engineering experience was gained in India, where he was engaged for several years in the construction of roads and bridges, as well as in the maintenance of long distances of mountain roads. In 1898 he was appointed Superintending Engineer to the late Mr. Edward Case, whose system of low groyning is so well known.

Amongst his chief works may be mentioned:—

"Foreshore Protection;" Transactions Society of Engineers, 1899. (The Bessemer Premium was awarded to the author for this paper.) London.

"The Sea as a Constructive Agent;" Transactions of Royal Scottish Society of Arts, 1900. (Silver Medal of Society.) Edinburgh.

"The Constructive Power of the Sea;" Transactions of the Institution of Civil Engineers of Ireland, 1902, vol. xxviii. (Silver Medal of the Institution.) Dublin.

"Notes on Road Construction;" Transactions of the Institution of Civil Engineers of Ireland, 1902, vol. xxviii. Dublin.

"The Youghal Foreshore Protection Works and Erosion on the East Coast of England;" Transactions of the Institution of Civil Engineers of Ireland, 1903. (Silver Medal of the Institution.) Dublin.

"The Protection of Foreshores by the Utilization of Tidal and Wave Action." (American Society of Civil Engineers, vol. l., p. 66, 1903.)

Mr. Winn, who practices as a Consulting Engineer in his own line in Dublin, is forty-eight years of age, and lives at Dalkey with his wife and sons. He is a B.A., a member of the Institution of Civil Engineers, Ireland, and of the Society of Engineers in London, a Justice of the Peace for County Kerry, and a member of the Oxford and Cambridge Club, London. His Dublin office, it may be mentioned, is at 22 South Frederick-street.

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